

“ЎЗБЕКИСТОН ТЕМИР ЙЎЛЛАРИ” АЖ

ТОШКЕНТ ТЕМИР ЙЎЛ МУХАНДИСЛАРИ ИНСТИТУТИ



Ҳимоя қилишга
руҳсат берилсин

Кафедра мудири

“ ” _____ 2016.й

“Электр транспорт ва юкори тез юрар электр харакат таркиби”
кафедраси

МАЛАКАВИЙ БИТИРУВ ИШИ

Мавзу: Investigation of system for management of locomotive traction motor" O'z-
EI "

(O'z EI электровози тортув двигателини бошқариш тизимини тадбиқ
қилиш.)

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Раҳбар:

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Тошкент – 2016 й.

«ЎЗБЕКИСТОН ТЕМИР ЙЎЛЛАРИ» АЖ

Тошкент темир йўл муҳандислари институти



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БАКАЛАВР БИТИРУВ МАЛАКАВИЙ ИШИ БЎЙИЧА ТОПШИРИҚ,

Талаба _____ Махкамов Шухратжон Шокиржон ўғли
(фамилияси, исми, шарифи)

1. Битирув ишининг мавзуси “Investigation of system for management of locomotive traction motor O'z-EI ”

2. Битирув иши мавзуси институтнинг 23.01.2016 йилдаги № 32-У буйруғи билан тасдиқланган.

3. Битирув ишини топшириш муддати 6 июнь 2016 - йил.

4. Битирув ишини бажаришга доир бошланғич маълумотлар Научно-техническая литература и материалы собранные в “O'zbekiston” lokomotiv deposi

5. Ҳисоблаш-тушунтириш ёзувларининг таркиби (ишлаб чиқиладиган масалалар рўйхати)

1. Introduction.

2. Technical characteristics

3. Traction motors

4. Traction control system of electric locomotive engine

5. The economy part

6. Occupational health

6. Чизма ишлар рўйхати (чизмалар номи аниқ кўрсатилади)

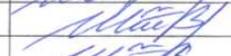
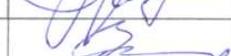
Йўқ

7. Битирув иши бўйича маслаҳатчи (лар)

№	Бўлим мавзуси	Маслаҳатчи ўқитувчи Ф.И.Ш.	Имзо, сана	
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1	Экономический раздел	Расулова Г	04.06.2016	06.06.2016

2	Охрана труда	Криворучко Б.В.		
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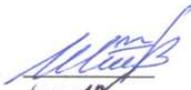
8. Битирув ишини бажариш режаси

№	Битирув иши босқичларнинг номи	Бажариш муддати (сана)	Текширувдан ўтганлик белгиси
1	Introduction	23.01.16	
2	Technical characteristics	01.02.16	
3	Traction motors	25.04.16	
4	Traction control system of electric locomotive engine	11.06.16	
5	The econom part	11.06.16	
6	Occupational health	25.05.16	
8	Подготовка презентации выпускной работы		

Битирув иши рахбари _____ Шадмонходжаев М.Ш.
(Ф.И.Ш)

Топширикни бажаришга олдим _____ Махкамов Ш...
(Ф.И.Ш)

Топширик берилган сана _____ 23 январ _____ 2016 йил


(ИМЗО)

(ИМЗО)

ESSAY

Graduation qualifying work consists of an introduction, __ chapters, conclusions, __graphics, __ tables, and references. In the second chapter-General information about asynchronous traction motor. Description of the structure of the traction electric motor. Structure of stator and rotor of asynchronous traction motor. Requirements for parameters of asynchronous motor traction. In the third and fourth chapter presents-TAE and execute management types of theoretical study on simulation of 4Qs converters.

Based on the calculations in the economic part of sh. use suggested Mahkamov more expensive semiconductor elements because this solution will simplify the operation and between repair runs under these conditions.

In the section "safety at work" was considered touch single-pole electrical safety in electrical installations up to 1000 in

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Каф.Каф		Бердиев У.Т		
Essay			Лит.	Лист
			9	Лист
			Тош ТИМИ "ЭТ ва ЮГЭХТ"	

Реферат

Выпускная квалификационная работа состоит из введения, 6 глав, заключения, ____ рисунков, ____ таблиц и ____ наименований списка литературы.

В второй главе – Общие сведения об асинхронном тяговом двигателе. Описание конструкции тягового электрического двигателя. Строение статора и ротора асинхронного тягового двигателя. Требования к параметрам тягового асинхронного двигателя.

В третье и четвертое главы представлен - типы управление ТАД и выполнение теоретических исследований по моделированию 4-х квадратного преобразователи.

На основании расчетов в экономической части Махкамов Ш. предложил использование более дорогих полупроводниковых элементов так как данное решение упростит эксплуатацию и межремонтные пробеги в данных условиях.

В разделе «Охрана труда» была рассмотрена электробезопасность однополюсного прикосновение в электроустановках до 1000 В

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Исп. Каф	Бердиев У.Т					Тош ТИМИ “ЭТ ва ЮТЭХТ”		

Referat

Bituruv malakaviy ishi 6 ta asosiy bo'lim, kirish, xulosa, _ rasmlar, _ jadvallar, va _ foydalanilgan adabiyotlardan tashkil topgan.

Ikkinchi bo'lim TAD to'g'risidagi ma'lumotlar haqida. TEM konstruksiyasi to'g'risida. TAM larning stator va rotor tuzilishi haqida. Tortuv asinxron motor parametrlari talablari.

Uchinchi va to'rtinchi bo'limlarda tortuv asinxron motortlarining boshqarish usullari va 4 kvadrantli o'zgartirgichini modernizatsiyalash bo'yicha nazariy tadbir qilish.

Mahkamov Sh. Hisobiga ko'ra foydalanish va ta'mirlash oralig'ida narxi yuqori bo'lsa ham ushbu yarim o'tkazgichlar eng yaxshisi bo'lib chiqdi.

Mehnat muhofazasi bo'limida 1000 v gacha bo'lgan elektr jihozlarga yaqinlashishda elektr xavfsizligi ko'rib chiqildi.

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INTRODUCTION

In the Republic of Uzbekistan carried out deep and large scale economic reforms aimed at formation of a socially oriented market economy, the main objective of which is to provide a decent standard of living for the people, increase production efficiency, quality and competitiveness of domestic goods and services, and strengthening the economic independence of the country. In modern conditions of dynamic and smooth functioning of most of the major actors of the economy and every region of the country is closely connected with the work of railway transport. It is typical for the railways transport availability factors and cheap transport become increasingly decisive in the development of the economy.

Currently, the rail transport accounts for over 60% of the total turnover of all transport modes. The role of railways in the provision of foreign economic relations of the Republic. Their specific weight in the development of export-import cargoes is over 80%. Rail transport is essential and with passengers. The proportion of railroads expensive account for about 22% passenger long-distance communications for all modes of transport and 13% passenger traffic of all kinds of suburban transport. In rail transport, cost of transport of goods by road compared to an average of 3-5 times lower against aircraft in 12-15 times. Labor costs for rail transport is also much smaller than road and air transport. In addition, rail transport especially in ecologically pure electric is much cleaner than other modes of transport.

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выпол		Махкамов Ш..					
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Зав.каф		Бредиев У.Т.					
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Rail transport differs from other modes of transport on a number of its indisputable advantages: high carrying and traffic capacity, low cost transport compared to road and air transport, high productivity, low fuel consumption metal and other operating materials per unit transport, a high level of environmental performance, especially when the electric range.

The main disadvantages of railways are: a great need for initial investments, relatively low maneuverability and mobility in the Organization of transport, great delivery time as opposed to air and road transport. In rail transport as a result of prolonged downtime of rolling stock under loading, unloading and stacked high enough proportion by initial-end transactions costs on traffic operations are relatively small. Because of these features of the railways are effective at transporting bulk goods over long distances.

Improvement of technology of cargo transportation is achieved by the introduction of progressive methods of organization of their delivery from warehouse to warehouse to consumer. These methods cover the streamlining processes like transportation to the main sections of railways between the stations of departure and destination stations, and initial-end operations based on the transportation of cargo to the station of departure and export them from the destination station to direct consumers.

One of the main directions of improving technology of cargo transportation for locomotive railway company of the Republic of Uzbekistan farms is a rational type of rolling stock, taking into account the specifications and properties of the goods, the customer's requirements to the quality of the transport. It is precisely in order to achieve this goal, 26.04.2002 years between State joint-stock railway company "O'zbekiston temir yo'llari" and locomotive building plants of the people's Republic of China was awarded a contract for the purchase of PIU-001\768 12 units of modern electric locomotives, able to perform cargo and passenger transportation.

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Locomotive Depot "Uzbekistan" was founded in May 1997 of the year on the basis of paragraph servicing locomotives (PTOL) Uzbekistan. At present, the locomotive Depot "Uzbekistan" is one of the largest enterprises of the COMPANY "o'zbekiston temir yo'llari" which performs a 46% of transport volume. In the locomotive Depot operated and repair different types of locomotive-electric locomotives, main-line and shunting locomotives and motor wagon rolling, (MULTIPLE) in the volume-2,-3, OR-1, OR-3. Successfully assimilated repair and maintenance of electric locomotives of series «Uzbekistan» production of the people's Republic of China. The depot created all conditions for normal work, recreation and improving knowledge workers.

Operational manual repair locomotives assigned to the Deputy Chief of the depot for the repair, which are subordinated to dispatch the unit for repair, the senior master repair shops, stations and offices. Dispatchers are interchangeable assistants Deputy Chief depot for repair and manage the entire process of repairing locomotive, ranging from performances at the repair to the release of the repair. They receive detailed information on the progress of repair works and for each repaired lokomotive lead network scheduling, as well as systematic analyse violations of graphics. Dispatchers instruct masters to regulate labour Bureau orders on filing for maintenance positions of spare parts, materials, etc. for greater responsiveness in the supply of spare parts and supplies for maintenance positions directly to the Manager of the Bureau of orders and transport Brigade.

The operational work of dispatchers enables Depot, wizards, and other engineers and technical workers to pay more attention to technology of repair quality control. In the locomotive Depot master plays a big role, which is a full head and direct production and labor organizer on their site work. Master

Depot manages the complex and specialized teams, consisting of workers in various professions, performing repair of locomotives and other works.

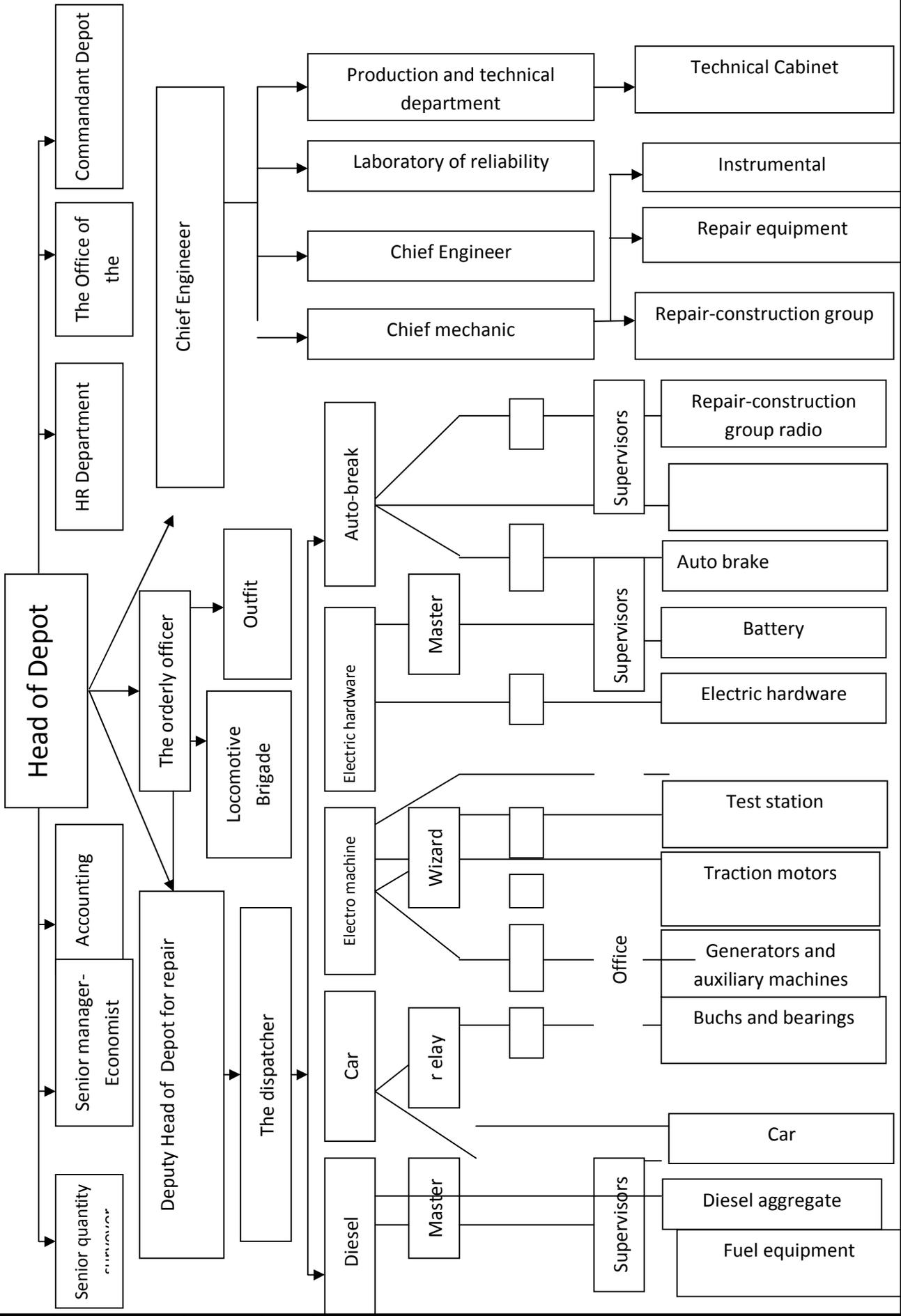
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Brigade is headed by foreman, who is a senior worker of usually not relieved of production duties, receiving for Brigadier supplement to the tariff rate. Foreman conducts coaching work, provides them with technical assistance in performing tasks, provides high quality work on time, labor discipline in the Brigade, safety equipment and tools, effective use, conserving materials.

Master Depot manages the complex and specialized teams, consisting of workers in various professions, performing repair of locomotives and other works. Brigade is headed by foreman, who is a senior worker of usually not relieved of production duties, receiving for Brigadier supplement to the tariff rate. Foreman conducts coaching work, provides them with technical assistance in performing tasks, provides high quality work on time, labor discipline in the Brigade, safety equipment and tools, effective use, conserving materials.

Due to the fact that the locomotive Depot "Uzbekistan" on 2005 year introduced organization of the aforementioned site, suggest creating it according to the following work. Repair services for locomotives, series "Uzbekiston"-is designed to prevent, detect, repair with the Elimination of defects and malfunctions of electronic equipment, electric apparatus, equipment auto brake, glass and other components of electric locomotives of the series "Uzbekistan".

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2. Technical characteristics of electric locomotive “O’z-el”

2.1 About electric locomotive “O’z-el”



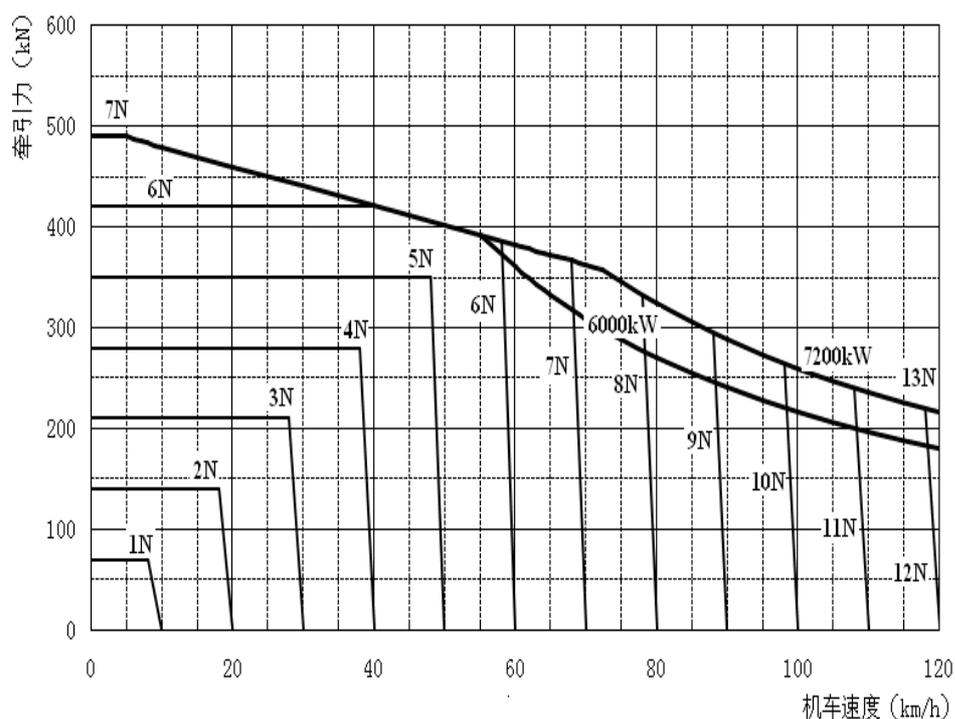
The new locomotives are designed for operation in a mountainous area on the electrified railway sections Marokand-Karshi-Termez. They save electricity consumption from 5% to 8% due to regenerative braking installations meet modern international requirements of ecological safety, equipped with asynchronous traction motors Toshiba (Japan) which do not have collectors and coal, which have a negative impact on the environment.

Electric locomotives are also equipped with a microprocessor-based system trouble shooting, resource consumables increased by 15% due to application of modern composite materials, air bladders provide a reliable locomotive operation in any climatic conditions.

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Зав.каф		Бредиев У.Т.					

Axial formula C0-C0
Axle load 23 tons
Pulling capacity 6000kW
Maximum starting tractive power 490kN
Regenerative braking power 5400kW
Maximum electric braking 278kN
Maximum speed 120 km/h
Continuous speed: 55 km/h
Power factor 0.98
Highest efficiency 0.85
Wheel diameter 1250 mm
Brake air braking mode plus regenerative braking

Traction control characteristics curve

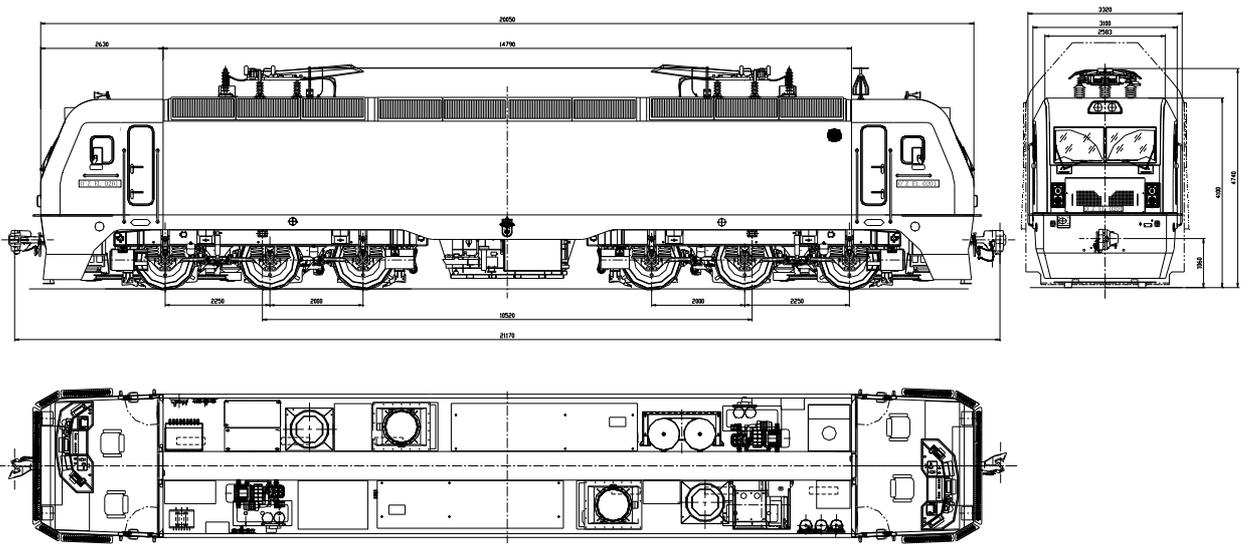


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The location of the general scheme of locomotive equipment



On the two ends of the locomotive cab installed separately Machinist, mechanical cabin is situated in means of the Machinist cabin. The mechanical cockpit installed central aisle width 600 mm Location equipment in locomotive (transformer, cooling tower, traction motor blower, compressor) is basically oblique symmetry plane. Equipment is installed in completeness, this is useful for weight distribution of the locomotive, locomotive manufacture, repairs and interchanges in nodes.

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3. Traction motors

3.1. Development of design and working principle of traction engines

Development design of traction motors is closely connected with the improvement of the design of their control systems. Historically, the rolling stock of all types of electric transport built with reservoir traction engines. This is due, primarily, simplicity of power transmission and control modes of its operation. These engines have a usable transport mechanical characteristics. However, commutator motors have some disadvantages, related mainly to the presence of the reservoir. The collector that has movable contacts (brushes), requires regular maintenance. To ensure reliable switching, reduce sparking motor design is complicated. In addition, it limits the maximum rotational speed, which leads to an increase in the dimensions of the engine.

Development of power semiconductor technology, with high performance, allowed in the 1960-80 years of the first to abandon the rheostat reservoir control system traction engines, replacing the more reliable and economical impulse, and then go on to produce cars with asynchronous traction drive. Domestic first subway mass-produced models type cars with impulse regulation became the type 81-718/719 in 1991, and the first serially manufactured type of wagons with asynchronous engines — “Yauza” 81-720.1/721.1 in 1998 year.

8 March 1889 year greatest Russian scientist and engineer Mikhail Osipovich Mikhail Dolivo-Dobrovolsky invented the three-phase asynchronous motor with short-circuit rotor. Induction motor is an asynchronous machine designed to convert AC electrical energy into mechanical energy. The very word "asynchronous" means not simultaneous.

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проверил		Шадмонходжаев						
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It is because of that asynchronous motors rotation frequency of the stator magnetic field is always greater than the frequency of rotation of the rotor. Work asynchronous motors, as is clear from the definition, from the network of alternating current.

Modern three-phase asynchronous motors were converters of electrical energy into mechanical energy. Due to its simplicity, low cost and high reliability of induction motors have been widely used. They are present everywhere, this is the most common type of engines, they produced 90% of the total number of engines in the world. Asynchronous motor truly committed a technical revolution in the world of industry..

The stator has a cylindrical shape, and is assembled from sheets of steel. In the grooves of the stator core stacked stator winding made of wire. The winding axis shifted in space relative to one another at an angle of 120° . Depending on the voltage of the winding ends are connected by a triangle or star.

Asynchronous motor rotors are of two types: squirrel-cage and wound-rotor. Squirrel cage rotor is a core, recruited from sheets of steel. Into the grooves of the core is filled with molten aluminum, resulting in rods that are closed-circuited end rings. This design is called a "squirrel cage". High power engines instead of aluminium may be used copper. Squirrel cage rotor winding short circuit represents where the actual name. The principle of work when submitting to the windings of voltage in each phase of the magnetic flux is created, which changes with the frequency of the supply voltage. These magnetic flows shifted relative to each other at 120° , both in time and in space. The resultant magnetic flux turns while rotating.

The result of the stator rotating magnetic flux and thus the rotor conductors in the EMF. Since the winding rotor, is a closed circuit, it was current, which in turn interact with the stator's magnetic flow, creates the starting torque of the motor, turn the rotor in the direction of rotation of the magnetic field of the stator. When he reaches the brake rotor, and then exceeds it, the rotor begins to rotate. This is a so-

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called slip. S-slide this value, which indicates how synchronous frequency n_1 the stator magnetic field more than n_2 , rotor speed as a percentage. Glide is extremely important. In the initial time it is equal to 1, but the increasing frequency of rotation of the rotor relative frequency difference $n_2 n_1 - n_2$ becomes smaller, resulting in reduced VOLTAGE and current in the rotor conductors, which entails a reduction in torque. In idle mode. When the engine exceeds this value, it can happen a so-called rollover engine and result in consequence to his nominal mode-1-8%. As soon as the equilibrium between electromagnetic point of rotation of the rotor and brake the moment generated by the load on the engine shaft change processes magnitude will cease. It turns out that the principle of operation of asynchronous motor is in the interaction of the stator rotating magnetic field and currents, which are adduced the magnetic field in the rotor. Moreover, the torque may occur only if there is a difference between rotation speed of magnetic fields.

3.2. Is the advantage and disadvantages of traction induction motor

To the advantages of this type of engines, in particular, before asynchronous motors with wound rotor motors are easy to service and no moving contacts. There are no brushes and slip rings, food is served only on the stationary stator winding three phases, what makes this engine extremely convenient for a variety of applications, almost generic. Such an engine is simple to manufacture and relatively cheap costs of exploitation are minimal and the reliability is high. If the load on the engine is not sensitive to its rotation speed of the rotor, if you do not want to speed control, then maybe enabling engine to any network without any additional converters.

In fairness, it is worth noting that when you include such a three-phase motor in single-phase network connection is required starting shifting capacitor, that is not a problem. If we talk about the disadvantages of asynchronous motors with squirrel cage rotor, then there are several of them. When you turn on the engine in-rush current network is quite large, with a starting torque significantly less than nominal,

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this somewhat limits the scope of application, and if you want a large starting torque, asynchronous motor with short-circuit rotor will not work. However, this disadvantage can be overcome using frequency converter, which allows you to smoothly increase the momentum, and thus to ensure a sufficiently high starting torque.

Speed control problem also occurs, but also solve it can be similarly, again using a frequency converter. Modern semiconductor frequency converters base makes every year more accessible. Another disadvantage of asynchronous motors with squirrel cage rotor is their low power factor, especially at low throttle and idling that reduces the effectiveness of the electrical system as a whole. Enterprise-wide it can result in substantial losses, therefore, the widespread practice of application of reactive power compensation systems when running in parallel with the motor windings set compensating capacitors.

The main disadvantages of asynchronous motors are the complexity of regulation and complexity of implementation of electric braking when using motors with squirrel cage rotor. Therefore, the design being developed Traction drives, using synchronous motors with permanent magnets rotor, ventilated no-inductor engines. 2.3 speed control of the induction motor, the following are the most common methods of speed regulation of asynchronous motor: change the additional resistance rotor circuit voltage change, supplied to the stator winding of the motor to change the frequency of the supply voltage, as well as switching the number of pairs of poles.

Asynchronous motor speed control by imposing a resistors in the circuit of the rotor. Introduction of resistors in the circuit of the rotor leads to increased power losses and reduce the frequency of rotation of the engine by increasing the slip, because $n = N_0 \cdot (1-s)$. Speed control asynchronous motor stator voltage change. Changing the voltage supplied to the stator winding asynchronous motor, enables you to adjust the speed using relatively simple technical means and control schemes.

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For this purpose between the network of alternating current with a standard pressure U_{1nom} and motor stator voltage regulator is included. Rotation speed regulation of asynchronous motor changing voltage supplied to the stator winding, critical time M_{cr} asynchronous motor proportionally to the square of the supply voltage to the motor U_{ret} (fig. 3) and slid from U_{reg} is independent.

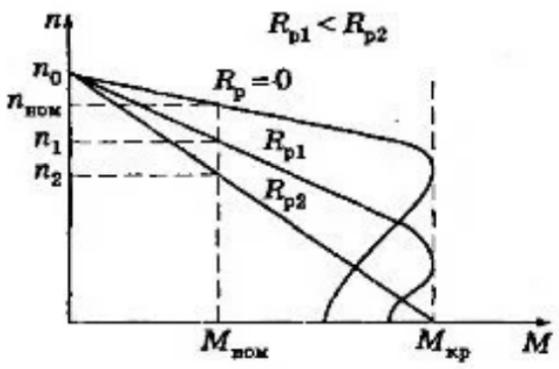
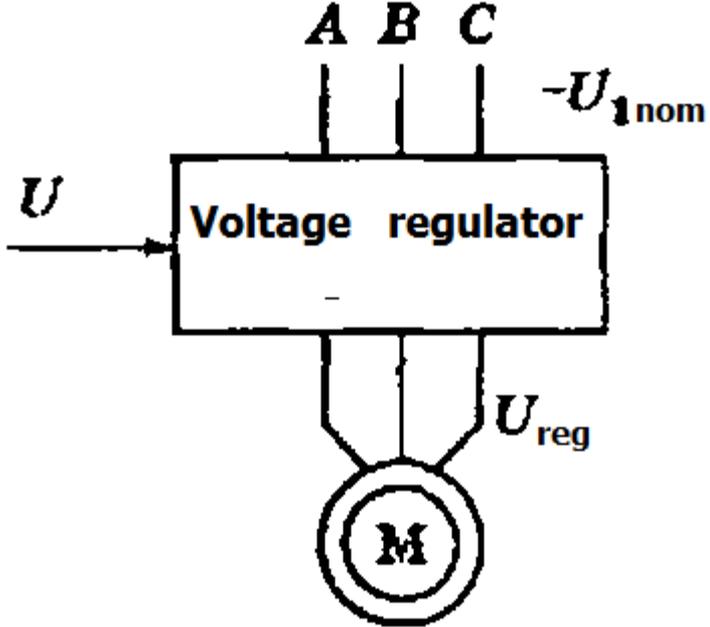


Figure. 3.1. Mechanical characteristics of asynchronous motor with wound rotor with different resistances of



resistors included in rotor circuit

Fig.3.2. Speed regulation scheme of asynchronous motor by changing the voltage at the stator

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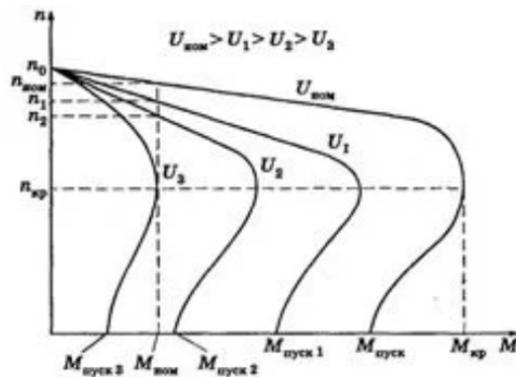


Figure. 3.3. Mechanical characteristics of asynchronous motor when the voltage change input to the windings of the stator

If the moment of resistance of the working machines more motor starting torque ($M_s > M_{start}$), the motor will not rotate, so you should run it at rated voltage U_{nom} or at idle. Adjust the frequency of rotation of short-circuited this way asynchronous motors can only when the nature of the fan load. In addition, it should use a special electric motors with high sliding. A small adjustment range up to n_{kr} . To change the voltage used three phase autotransformers and thyristor voltage regulators.

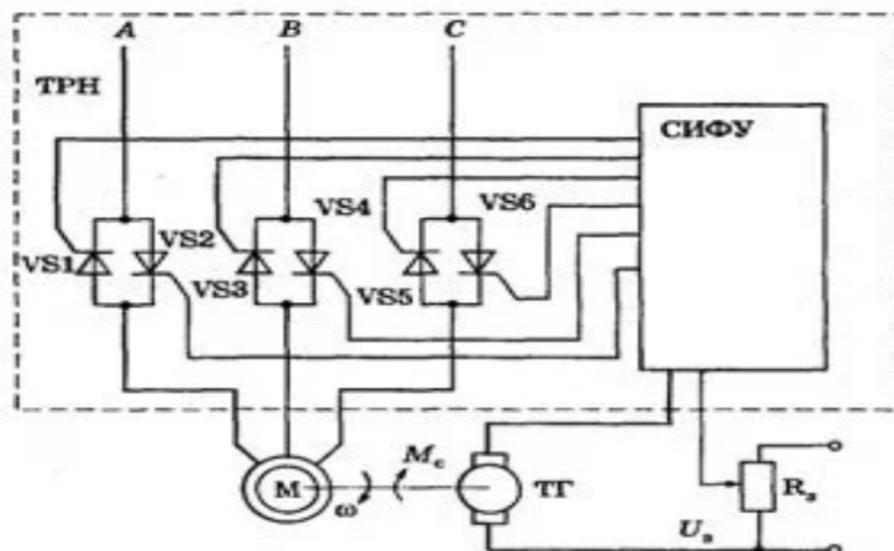


Figure. 3.4. speed regulation system diagram of thyristor voltage regulator-asynchronous motor

Closed-loop control scheme of asynchronous motor, executed according to the scheme of thyristor voltage controller-motor allows you to adjust the speed of asynchronous motor with high slip (these engines are used in ventilation systems).

Speed control asynchronous motor changing frequency of supply voltage so as the speed of rotation of the stator magnetic field $n_s = 60f/p$, speed control asynchronous motor can produce a change in the frequency of the supply voltage. The principle of frequency speed control method of asynchronous motor is that by changing the frequency of the supply voltage in accordance with the expression while the number of pairs of Poles p change the angular velocity, no magnetic field of the stator. This method provides smooth speed control over a wide range, and mechanical characteristics of high hardness. To obtain high energy performance of asynchronous Motors (power efficiency coefficients, handling ability) you must at the same time with the frequency change and supply voltage. The law changes the voltage depends on the nature of the load moment M_s . At constant voltage at the load moment stator must be proportional to the frequency. With decreasing frequency (f) critical point n_{cr} decreases in small rotation. This is due to the growing influence of stator winding resistance while reducing frequency and voltage. Frequency speed control asynchronous motor allows you to change the speed range (20-30): 1. Frequency method is the most promising for regulation of asynchronous motor with short-circuit rotor. Power loss in such management is small, since the minimal losses. Most modern frequency converters built on double conversion scheme. They consist of the following main parts: DC link (unmanaged rectifier) power pulsed inverter and control system of DC formation consists of unmanaged rectifier and a filter. AC voltage is converted it into DC voltage. Power three-phase Pulse inverter contains six transistor keys.

Each motor winding is connected via appropriate key to positive and negative findings of the rectifier. The inverter converts the voltage in rectified three-phase AC voltage desired frequency and amplitude, which is attached to the stator windings of an electric motor. The output stages are designed as keys used inverter power IGBT transistors. Compared with thyristors they have higher frequency switch that allows you to generate a sinusoidal output signal forms with minimal distortion. Regulation of output frequency and output voltage $U_{out} \approx U_{nom}$ is due to high-frequency pulse-

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width modulation. asynchronous motor speed control switch the number of pairs of poles. Stepped speed control can be accomplished by using special multispeed induction motors with squirrel cage rotor. No expression = $60f/r$ should be that if you change the number of pairs of Poles r produces mechanical characteristics at different speeds no magnetic field of the stator. Because the value of r is defined by the integers, then the transition from one to the other characteristics in the regulatory process is stepwise in nature. There are two ways to change the number of pairs of poles. In the first case the stator grooves placed two windings with different numbers of poles. When you change the speed of the network connects one of the windings. In the second case, the windings of each phase constituted of two parts that connect in parallel or sequentially. The number of pairs of Poles changed twice. Speed control by changing the number of pairs of Poles economically, and mechanical specifications retain rigidity. The disadvantage of this method is benched nature changes often.

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4. Traction control system of electric locomotive engine

4.1. Types of control asynchronous traction engine

The Office is the impact on the object aimed at achieving this goal. The train is moving it from the starting point to the end station for a set amount of time schedule while ensuring the safety of traffic and minimal energy consumption. For this train speed V must be changed in a certain dependence on the distance covered. The objective will be achieved if locomotive implements traction force F_k , sufficient to overcome the resistance force trains W and to create the required accelerate train dV/dt . If necessary, reduce the speed of trains ($dV/dt < 0$) would require the creation of brake force directed back to the vector velocity V . The locomotive features to implement traction and braking force defines its traction and braking characteristics that represent dependencies $F_k(V)$ and $(B)(V)$ and have restrictions on forces F_k and defined the parameters of the locomotive. The management of the COMPANY is to create certain operating modes of the traction motors (TEE), which are provided with the required values of traction force F_k (or brake force) under specified speeds V . The operation mode is determined by the voltage on its TEE clips U_d , excitation current I_B , and for TED even AC and a frequency of f_d .

The combination of devices designed to change the behavior of TEE, is called ER control system . The first core function is to regulate ER mode of operation TEE, with a view to ensuring the movement of trains according to a schedule. Power supply system of Electric Railway provides electricity supply to pantagraph ER. It is known that capital expenditures for the construction of power-supply system and annual energy losses can be reduced by using a higher rated voltage contact network.

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выпол		Махкамов Ш..					
проверил		Шадмонходжаев			ЛИТ	ЛИСТ	ЛИСТ
					ТошТЙМИ “ЭТ ва ЮТЭЎТ”		
Зав.каф		Бредиев У.Т.					

However, it becomes impossible to directly power the traction motors supplied with contact system voltage on TEE should not exceed 1500, and optimal parameters of TEE when $U_d = 700$. 1000 w. so the second basic function of SU is to convert the ER contact system voltage current type U_c and it characterized by frequency of contact network FC, in voltage and type of current, suitable for TEE (U_d and f_d). In addition, Su ER must perform the following additional functions:

- speed limits, the force of traction and electric braking according to the parameters of the ER and the requirements of traffic safety;

- the protection of electrical equipment against damage and dangerous regimes; -air cooling electrical and compressed air for pneumatic actuators;

- Automation of management of ER.

To perform basic and advanced features of the control system of ER in accordance with the terms of the trains, you must toggle the work ER. These switches implements a machinist that their actions must take into account modes of TEE (U_d , I_d , I_B) and power supply systems (U_c) traffic conditions, trains (V , dV/dt , i , S), as well as safety requirements.

The smallest energy consumption at a given time of progress provides a mode of motion of the train at a constant speed of $V = \text{const}$. However, on different sites the way you want to implement different speeds. In particular, before departing trains, as well as after his stop $V = 0$. There is therefore a need to move from one steady velocity values to another. It must be understood that the sudden change of the magnitude of the acceleration is perceived as a blow, which creates additional load on the structure of the rolling stock and causing discomfort among people in the train. You should therefore provide for smooth change accelerating, maintaining a constant rate of change of acceleration $d^2V/dt^2 = \text{const}$. The service and adjusting braking should take $dV/dt = 0.5 \text{ m/s}$ and $d^2V/dt^2 = 0.25 \text{ m/C}$, and an emergency-
 $dV/dt = 2.2 \text{ m/s}$ and $d^2V/dt^2 = 10 \text{ m/C}$
 Thus, the control system should include three basic modes of train movement: $V =$

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const, $dV/dt = \text{const}$ and $d^2V/dt^2 = \text{const}$. Taking into account the real forms of traction characteristics and use run-on dependence of $V(t)$ will have the form shown in Fig. 1.1 dashed line. As is well known, established train speed is determined by the point of intersection characteristics of full resistance $W(V)$ and traction $F(V)$. That when the same speed train had accelerated dV/dt , traction force must be equal to the $F_z = F_y + (1 + \gamma) m_p dV/dt (Z)$. Here is the mass m_p trains, $1 + \gamma$ is a coefficient of inertia of rotating parts. The required values are set to their train speed required speed of communications traffic safety conditions as well as the variation of the resistance movement, weight trains and profile path. Diversity of conditions of train movement confronts SU ER requirement to enable the relevant regimes any points within the existing limitations of the traction change ER $F_k(V)$ coupling-1, 2-speed and valid to TEE-3.

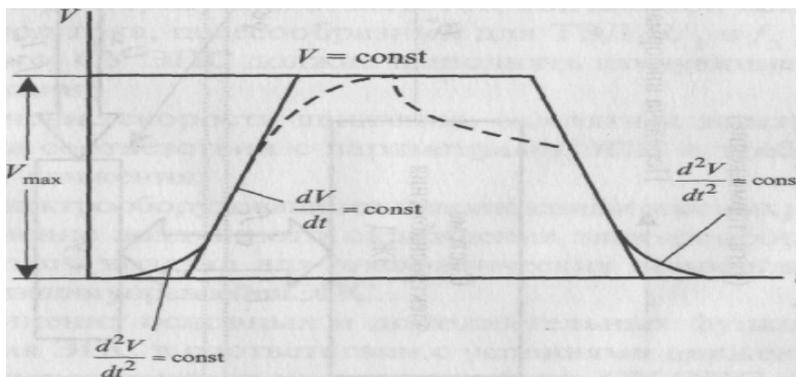


Fig. 4.1. Modes of train movement

Stepwise regulate traction force by switching from one traction characteristics to another is accompanied by change of traction force F within $F_4 \leq F \leq F_3$. Since there are no ER devices that measure the traction force directly, its magnitude is usually judged indirect indicator-current traction motor (I) that is associated with the pulling force F known ratio $F = SFI$, where c is the constant coefficient that depends on the parameters of TAM and traction transmission; S -magnetic flux TAM

Overview of patent sources pulse regulation of TEE The traction motors (TEE)

ER the following requirements :

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- possibility of realization of large capacity in a limited size;
- the ability to control the speed and traction force widely;
- simplicity in design and reliability.

Currently the most common ER manifold TEE DC and pulsed currents, which have good traction and are easy to regulate. Their disadvantages are associated with the presence of the reservoir, which increases the cost of production and labour exploitation TEE restricts active length of anchors and power of TEE, as well as limit the maximum speed of rotation. Traction force and speed of such changes are governed by U_d and TEE I_b . Feature collector TEE single-phase current is the presence of transformer EMF in windings section switched anchors. To limit this EMF lower frequency voltage and reduce the magnetic flux. To provide the required power needs to be increased number of Ted poles up to 14. 16. Accordingly, the number of brush holders. Switching conditions limit the amount of voltage up to 250 ... 500 for the realization of the necessary capacity needs to be increased motor current and hence increase the lengths ..

The advantages of this TAE: no collector removes restriction of power at high speeds, makes it possible to increase the voltage to the engine, which is limited only to insulation, allows you to adjust the power factor. Disadvantages: the complexity of the management system and the need for synchronization control thyristors with rotor position that requires a different voltage and frequency converter on each engine.

Asynchronous TRACTION MOTORS with wound rotor motors are applied on ER in the United States in the early 20th century. Their speed is regulated by change of the resistance in the rotor circuit. The COMPANY currently uses asynchronous short-circuit TEE, that have a very simple design and low cost, but they require complex control system that ensures smooth regulation of frequency and voltage.

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Despite this, ER with asynchronous TEE let out some of the leading locomotive construction companies (Siemens, ABB, Ansaldo, Toshiba). SU ER without converters. Historically, the first locomotives had the simplest SU without converters. Such SOO provide stepwise voltage regulation on TAE Udza by changing factions TAE, regulation of excitation current IB and inclusion of starting resistors r (for ER DC) or switch the number of revolutions of the windings of the transformer (ER AC). Apply collector TEE DC (CBT) and single-phase commutator. Advantages of the SU without-converters are their simplicity and cheapness, the disadvantages are significant losses in starting resistors, gradation of regulation

In 1947-1955 years get the development of normal frequency AC United States, France and Hungary appear a variety of electric locomotives with rotary converters have commutator DC TRACTION MOTORS or asynchronous TRACTION MOTORS with squirrel cage rotor. Speed control is carried out by change of voltage and frequency of the traction motors . Such SOO had many advantages:

- (a) capability use TEE with optimal parameters regardless of the voltage and current type in the contact system;
- b) smooth regulation of speed and traction; sinusoidal current form), consumed of contact network, and the possibility of regulating power factor due to the use of the converter with synchronous motor .

However, ER with rotating converters were characterized by two major problems: a) a large electrical weight per capacity unit TEE . Given the load limit of the wheels on the Rails on the construction ways such locomotives can have no more than 400 500 kW power in driving axle; b) relatively low efficiency of electric locomotive, due to three quintuple energy conversion. After 1955 years such locomotives were no longer available.

In the early postwar years in the United States, France and the USSR built and tested electric locomotives with static converters of the first generation, on which

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one anod used mercury arc rectifiers. Their shortcomings: the complexity of the design; the difficulty of ensuring the tightness of the appliances in terms of vibration of rolling stock; the need to maintain the temperature of the rectifier in the narrow limits 35. 40° c, which required the use of water cooling; locomotive prožoge mercury contamination casing rectifier. However, ER with mercury rectifiers had significant advantages over rotary converters: a much smaller mass per unit of electrical power of TED, and higher efficiency. The second generation of static converters appeared in Europe in 1958-1959, and four years later-in the Soviet Union. As rectifiers were used Silicon diodes. It is allowed to replace water-cooled air, reduce weight and dimensions rectifier unit, simplify maintenance, improve EFFICIENCY and reliability. Voltage at TED electric locomotives of the first and second generations were governed by changing the number of turns of winding of the transformer using the contactors. The advantages of these converters were so significant, that whenever the overhaul on all electric locomotives of the first generation of mercury arc rectifiers were replaced by Silicon. The third generation of static converters differ using managed semiconductor-Silicon thyristors. This allowed to renounce the use of contactors and switch to non-contact adjustment. In addition, it is now possible to recovery on electric locomotives with static conversion.

Now begins the fifth generation, characterized by the use of power semiconductors IGBT (Insulated Gate Bipolar Transistor-insulated gate bipolar transistor) and IGCT (Integrated Gate Commutated Thyristor-lockable thyristor with integrated control unit). Disadvantages of static converters:

- a) a significant reduction in deep power factor phase regulation in traction and regeneration modes;
- b) distortion of the shape of the curve of current consumed from the contact network, and) the need for reactive power compensation at the higher harmonics.

Implementation of theoretical study on simulation of 4-piece square converters. 4.1. Diagram and work 4-piece square inverters .

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Electric locomotives of various types should be harmonized among themselves. Analysis of circuits and designs sites main locomotives standing 3 kV and 25 kV AC, 50 Hz currents with asynchronous-traction engines shows that they can be harmonized on many positions: traction engines; some electric power conversion systems devices (inverters): ancillary equipment; device protection, governance and security; construction trucks, power transmission; devices links body with bogies and traction transmission etc. Such unification is beneficial and manufacturers of locomotives and those who operates, maintains and repairs.

Requirements to the characteristics prospective electric locomotives are set on the assumption that the main indicator of the success of the operation and development of the railways should be minimising the total cost per unit of useful work, and propulsion options are critical to the economy of transport. No less important in determining the parameters of propulsion is the need to create the optimal stock freight and railway capacity at maximum probable needs for transport and minimum investment. Actually provide the demand for transport services in the long term by increasing the weight of trains and the speed of their movement

Minimize operation costs can be in several ways:
1) increasing unit (axial) power to electric locomotives, you can actually use the clutch condition

2) lowering the defectiveness and increasing availability;

3) improving performance technical equipment and staff;

4) reducing energy cost per unit of useful work;

5) ensuring staff security and safety of cargoes.

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The most rational way these goals can be achieved in the application of the prospective in electric train traction drive with asynchronous traction motors rated power of ADT (axial power) compared to permanent engine (pulsed) current more in 1.5 ... 2 times. This power can be used throughout the speed range, which makes electric locomotive with ADT universal. Experience of railways of GERMANY shows that due to this park locomotives may be reduced by 10%, and daily subsistence allowance increased by 35 runs. 50% . After mastering the production of high-speed semiconductor devices large capacity and high-performance microprocessors to create electric locomotives with TAM became a real challenge. Of the possible options of power converters and static schemes number of phases for AC electric locomotives are almost always used with the input schema 4q-S converter and stand-alone inverter voltage (SAI), and DC electric locomotives-scheme with the input pulse controller and stand-alone inverter voltage . When applying for an electric locomotive AC 4q-S converter with širokoimpulznoj modulation practically is not distorted form of contact system voltage and is provided when you change the load in a wide range of power factor close to unity. The inverters are high current surge which requires the application of semiconductor elements of higher classes and special measures of protection. DC inverter requires the input filter reactor with greater inductance (and weight), has a lower power factor compared to SAI .

Calculation and selection of semiconductor devices to the electric diagram of engine

power: = 1000 kW;

$$I = 1000 \text{ A}$$

$$U = \frac{P}{\sqrt{3} \cdot I}$$

$$U = \frac{1000}{\sqrt{3} \cdot 1000} = 578 \text{ В. (4.1)}$$

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Choose the type of transistor for single-phase Bridge: MTQI 1200-12; Choose the type of transistor for three-phase Bridge: MTQI 1800-12. 4Qs converter is two bridges (single-phase and three-phase) with transistors and inverse diodes, connected by DC voltage. By AC-consistently included inductive filter. By DC-parallel to the included capacitive filter. By single-phase bridge voltage contact network $U_{ks} = \text{const}$ and $f_{ks} = \text{const}$. By three-phase bridge voltage $U_{ATD} = \text{var}$ and $f_{ATD} = \text{var}$ (fig. 4.2).

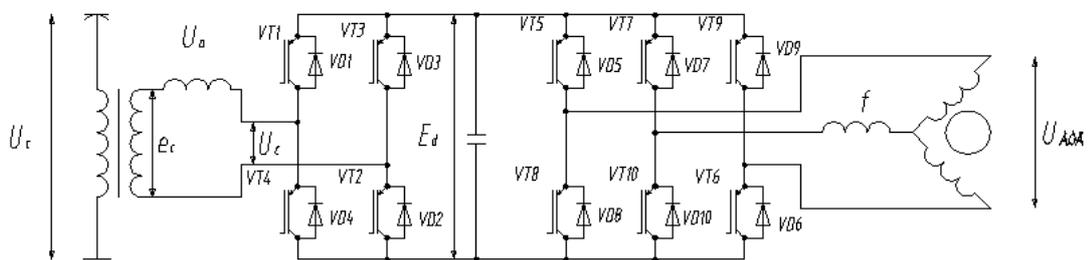


Figure. 4.2. Concept 4-Qs converter Concept 4-Qs converter.

The first samples of converter transformer used Siemens in 1979 year at an electric locomotive E120, had one operational thyristors with the contours of artificial switching. The name of the converter can be explained by the fact that the converter accepts work in modes of traction and braking. With the current consumed from the network may lag behind the network voltage, and outrun it. If the voltage vector coincides with the positive real axis direction, the possible modes of operation of the converter in which the network current vector is located in any of the four quadrants of the complex plane.

4-Qs converter operation modes are listed in the table. 4.1.

Table 4.1.

Modes	Bridge modes		Frequency modulating the voltage
AT	single-phase	Three-phase	
Rod	Transistors are closed, uncontrollable hair straightener $E_d = const$	AIN with PWM regulation f_{ADT} and UATD;	$f_M = f_{ATD}$
Braking	YING with PWM, constant frequency f_C , and the effective value of voltage U , regulation of the angle	Transistors are closed, uncontrollable hair straightener, $E_d = var$ due to ADT speed measurement	$f_M = f_C$

The principle of operation of 4-Qs converter easier to consider for example recovery mode when there is a single phase inverting. The work of single-phase bridge invert mode: constant voltage E_d on the condenser is converted into alternating voltage u_a . When this happens the alternation between the following modes: open two transistor in opposite VT1 VT2 and shoulders. The capacitor discharges to the secondary winding of the transformer with the persistence of polarity $u_a = e_d$. Current $i_a = i_d$ subsides (intervals 1-2, 3-4, 5-7, 6-8, 9-10 in Fig. 1. 2.1.) Current $i_a = i_d$ subsides. Open two transistor related shoulders VT1 and VT3. The secondary winding of the transformer is closed-circuited in the first p alternation through VD3 and VT1, the second alternation through VD1 and VT3. Current increases. Output voltage single-phase bridge $U_a = 0$. The capacitor is charged by three-phase bridge and separated from the single-phase, $i_d = 0$. Open two transistor in opposite shoulders and VT3 VT4. The capacitor discharges to the secondary winding of a transformer to change the polarity of the $U_a = -e_d$. Current $i_a = -i_d$ subsides opened two thyristors in adjacent shoulders VT2 and VT4 (time interval 0-1, 4-5, 8-9, 12-13, 16-17 and 20-(((on fig. 4.1.)

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Secondary winding closed circuited in the first alternation through VT2 and VD4, AVO second, alternation through VT4 and VD2. As in the case of 3.2, the capacitor is charging three-phase bridge and separated from the single-phase. Current i_a increases, $i_d = 0$. Thyristor control system compares voltage and $-u_m$ sinusoidal modulation voltage with frequency shifted in phase by an angle relative to the first harmonic voltage in the secondary winding of the transformer. The voltage produced by a special generator that allows you to adjust the angle. $(-u_m)$ is a sinusoidal voltage, shifted by 180.

While rewinning frequency modulating the voltage is equal to the frequency of contact network $f_M = f_C$, and with draught-stator frequency $f_{ATDfM} = f_{ATD}$. $-u_m$ saw-toothed voltage symmetrical shape with frequency (4.3) reaching a peak when passing through zero voltage modulating. The ratio of the frequencies and voltage modulating saw-shaped must be equal to a an odd number. In our example.

The opened State of transistors:

- VT1: $u_m \geq u_n$;
- VT4: $u_m < u_n$;
- VT3: $(-u_m) \geq u_n$;
- VT2: $(-u_m) < u_n$. Voltage in the secondary winding of the transformer E_a can be decomposed in Fourier series. The amplitude of the first harmonic of the output modulation depth is regulated by a number of μ , which is equal to the relative amplitudes of modulating and saw-shaped stress

$$\mu = \frac{u_{nm}}{u_{m\pi}} < 1 \quad (4.4)$$

When this

$$e_{ma1} = \mu \cdot E_a \quad (4.5)$$

$$u_M = U_{Mm} \text{SIN}(2\pi f_M t) \quad (4.6)$$

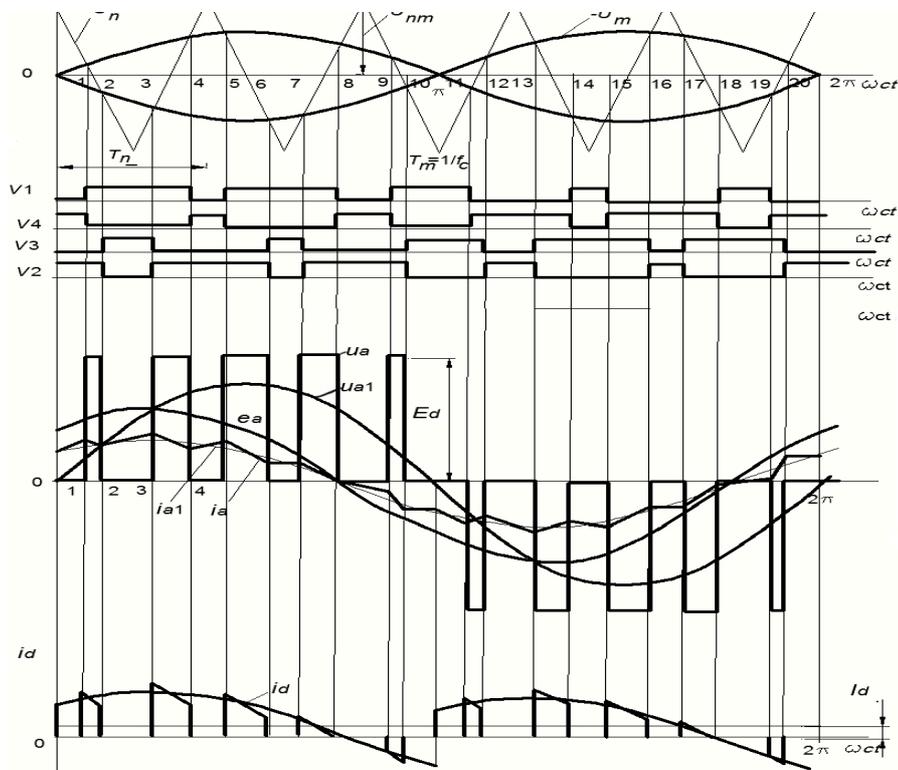


Figure. 4.3. voltage and current Waveform

Shear angle, φ_a between the first harmonics current i_{a1} and voltage e_{a1} is regulated by change the angle shear ψ between modulating the voltage u_m and voltage in the secondary winding of the transformer e_a .

Voltage on the primary winding of the transformer E_a equal to the geometric

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sum of inverter output voltage \dot{U}_1 and voltage drop on inductance $j\omega_a L_a \dot{I}_a$.
 Adjusting the angle Ψ between u_m and e_a you can have the angle Φ_a traction mode was zero, as in recovery mode -180° .

Uzbekistan railways electrified (voltage 25 kV) electric locomotives were used until recent years VL-60 and VL-80. At present, electric locomotives VL-60 exhausted their resource. Their replacements were purchased by electric locomotives of series «Uzbekistan», produced by locomotive building factory (China). These locomotives differ from the VL-60 that they used asynchronous traction motors and frequency inverter to regulate voltage and frequency (fig. 2.2). The locomotive is equipped with two traction converters. Each traction Converter includes: two 4Qs convertor pulse regulator; two pulse inverter (one for each traction motor); one inverter to power auxiliary on-board energy consumers. In all the components of the conversion as the element base used bipolar transistors (IGBT). When running on AC contact

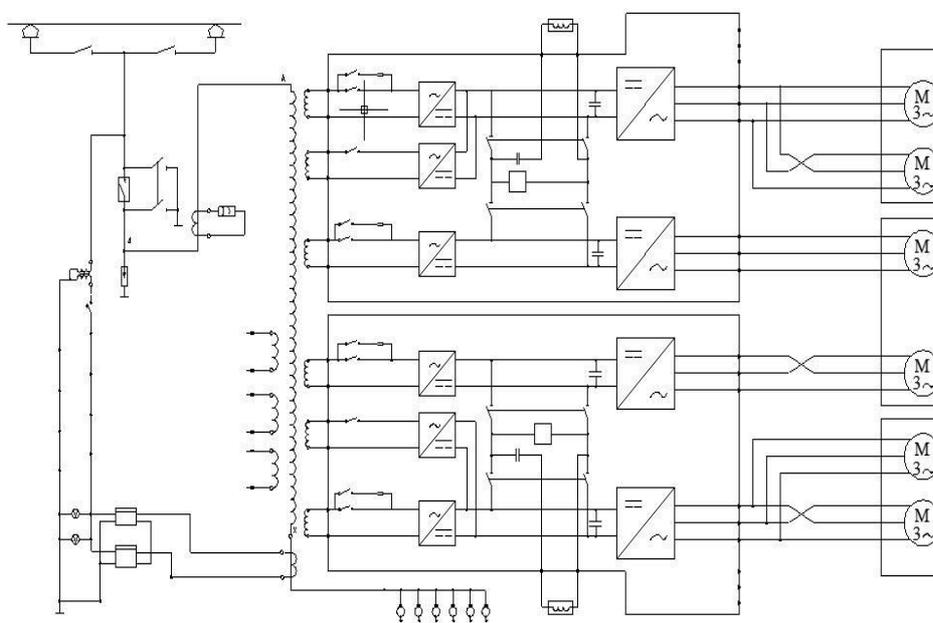


Figure. 4.4. Circuits diagram electric locomotive "Uzbekistan"

Circuits diagram electric locomotive "Uzbekistan" voltage of 15 or 25 kV traction current to the converter, previously going through the sequence of switching devices, which includes the disconnecter, earthing switch, inductive ballasts and main vacuum quick switch to the primary winding of the main transformer. Converter 4qS controllers connected to the secondary winding of the main transformer. Rectified current from them through the intermediate DC voltage goes to three pulse inverters. Each inverter feeds the three-phase alternating current traction motors. Leakage current is possible both in forward and reverse direction, i.e. implemented as modes of traction and electrodynamic braking. So, on the basis of the analysis, taking into account the peculiarities of traction motors to ER, such as a wide range of loads and operating temperatures; work in conditions of constant perturbation.

To maximize the potential of the engine and clutch wheel rail conditions control system asynchronous traction drive must have the following properties:

- to consider non-linearity characteristics of magnetization;
- to consider the thermal nonlinearity of rotor resistance;
- be insensitive to perturbations by the contact network; be insensitive to perturbations by the load.

The greatest of these requirements conform to the management system, implement the automatic maintenance of the permanence of magnetic flux-vector control.

4.2. Implementation of theoretical study on simulation of pulse voltage regulator..

Working principle of pulse energy converters Pulse energy conversion is achieved by periodic managed between turning off and turning on diodes thyristor circuit breaker etc. These are provided by step change of voltage applied to the load, and

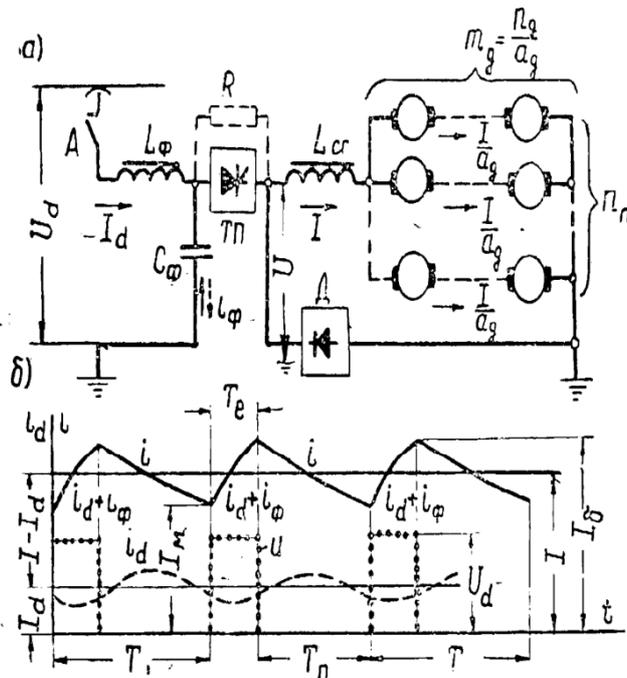
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intermittent change in the level of energy consumption from the power source. If thyristors is included in parallel some resistance as shown in Figure 1. a dashed line, then talk about impulse control, resistance. In cases where $R = \infty$, the place has a pulse voltage regulation . Enabling and disabling thyristors accompanied by Pulsations of the AC power source and load i_d \dot{i} . The continuity of the current i_d systems are provided through the inclusion of filter L_f - S_f at entrance. When switched off thyristors current i is supported by electromagnetic energy generated in load and smoothing the reactor through the circuit containing the group handling the diode d . availability of unloading the chain determines the inequality of average load currents and power source and makes it easier to turn off thyristors systems. Complex of devices containing a , filter, smoothing reactor and group diodes, called pulse energy converter . Thyristors systems and d usually performed constructive in one block. To disable the pulse energy converter from a source of energy, normal and emergency modes used automatic a. Chart changes currents at work of ICE is shown in Fig. , 6; Here the same dotted line shows the change.

$$\dot{i} = i_d + \dot{i}_\phi \quad (3-1)$$

where is the filter current \dot{i}_ϕ was placed.

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a) concept; b) modification of currents and voltages

In this interval the load current varies from a minimum to a maximum I_b . In the interval of T energy from a source of energy not consumed, so current i , subsides from I_b to I_k . Source current

$$I_d = I_\phi (1 - \lambda)$$

and going on a charge capacity of the filter. Pulse mode energy consumption, in which changing currents and voltages within each period identically repeated. In this mode, the mean values of currents and voltages remain unchanged. Power supply voltage

$U_d = \text{const}$ attached to the load only in the interval. Therefore, the average value of the voltage at the load

$$U = \frac{1}{T} \int_0^T u dt = \frac{U_d T_e}{T} = \lambda U_d$$

$$\lambda = \frac{T_e}{T}$$

where

relative time energy consumption, which in the future will be called the fill factor.

Medium voltage to the condenser filter can remain constant only if the average level in the range of T_e equals the mean charge in the range of T_d . This condition can be written in the form of secondary currents:

(1-4) is determined by the ratio between the average values of the load current (I) and power supply I_d :

$$I_d = I \frac{T_e}{T} = \lambda I, \quad (1-5)$$

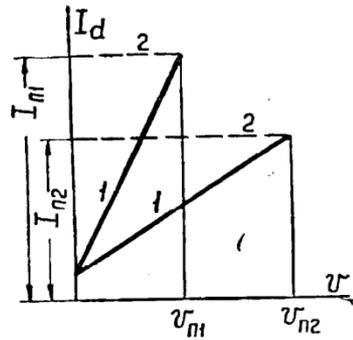
- so as

$$T_e + T_d = T \quad (1-6)$$

If the load is ER engines included in TAE parallel group, each current and voltage from traction engines:

$$I_d = \frac{I}{a_d} \quad (1-7)$$

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$$U_d = \frac{U a_d}{n_d} = \frac{U}{m_d} \quad (1-8)$$

where m_d is the number consistently included engines each parallel group. Thus change fill factor λ can be achieved the required voltage and current regulation of traction motors. Change management system λ . On mode changes λ are distinguished: latitudinal regulation where change Those when you save $T = \text{const}$; frequency regulation, when Those = const or $Tn = \text{const}$, and change the frequency

and pulse width frequency regulation combining simultaneous change. Some examples will be examined below under the assumption that thyristors are ideal switches. Instantly move from open to closed and vice versa.

Fig. 1-4. 1- When pulse management; 2 - with the seamless analyse management

4.2. Impulse voltage regulation for regenerative braking system with self-excited traction engines

Kerens self-excited pulse devoid of weaknesses in systems with continuous self-excited, and is sustainable in a certain range of speeds. Schematic IMPULSE VOLTAGE REGULATION while rewinding with self-excited is shown in Fig. 1-11, a. for simplicity here does not specify an input filter. Suppose that the inductance of the power source is negligible (e.g., recovery on the battery). Then will be considered only the voltage drop on inductance L traction engine circuit and in the active, total resistance $R + r$ labeled on the figure. 1-11, a. before braking with self-excited produced a reversal of traction engine, in order to avoid its demagnetization brake current.

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$$I_p = I (1 - \lambda).$$

For an interval (T—Te) According to the figure. 1-11, and true equality

$$E - U_d = L \frac{di}{dt} + i(R + r) = L \frac{di}{dt} + i \sum R,$$

(1—15) where $E = C\Phi$, traction engine. In Figure 1. 1-12, and dependencies (e) = 1 (i) for different speeds and direct

$$U_d + (R + r)i = \varphi_2(i),$$

angle to the x-axis, the higher the value of the $\sum R$. Pulse can be sustainable only when turning off when accompanied by decline in traction motor current. When

$$\frac{di}{dt} < 0.$$

(1-15) should note that this is only possible if

$$E - (U_d + i \sum R) < 0.$$

If the condition (1-16) are not fulfilled, then after turning off TRIAC IMPULSE VOLTAGE REGULATION traction motor current will increase until it reaches the point of equilibrium 2, Shown in Figure 1. 1-12, a. current in point 2 braking at high speeds usually far exceeds the value allowed for switching. Therefore, zone 1-2 will later call over area. Area sustained pulse recovery 0-4 increases with decreasing speed and braking zone 1-2 decreases. Below a critical speed zone enabled becomes zero and self-excited braking impulse always remains stable. The value of the critical velocity is determined by the ratio of

$$v_{кр} = \frac{U_d + i \sum R}{C\Phi}$$

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The critical speed start braking can be enhanced or the introduction of additional resistance or weakening the stream Φ . 1-12, 6 shows the restrictions imposed on the braking performance with some value and expanding the limits of braking the introduction of additional resistance so that $\sum R_1 > \sum R_2$ (see dashed line in Fig. 1-12). The inclusion of additional resistance reduces the effect of regenerative braking, as they can be extinguished a large part of energy emission.

4.5. Perform theoretical study on modeling of the auxiliary inverter voltage

At the entrance of AIN (fig. 4.5.1) install energy storage in the form of a capacitor with large capacity; thyristor shoulders VS1-VS6 inverter united return shunt diodes VD1-VD6, thereby ensuring the unimpeded circulation of reactive energy between HELL and the condenser. At the outlet of three phase voltage adjustable receive the auxiliary inverter voltage frequencies whose value is determined by the input voltage (E) inverter.

At auxiliary inverter voltage under conditions of permanence of the input voltage. infinitely large capacity Cd filter capacitors, and instantaneous switching thyristors form the output voltage does not depend on the properties and parameters for the load. Harmonic composition of output voltage is constant, always the main harmonic component $E_1 = \sqrt{2} E / \pi$, where e on input inverter The most common in the study of the system AIV- asynchronous motor so far is the so-called method of harmonic motors. It presupposes the existence of a number of equivalent engines with a common shaft with parameters that correspond to the frequencies of the main and the largest amplitude higher harmonic components. This method is time-consuming and to achieve the necessary precision of calculation requires the use of computers. Additionally, due to the phase shift harmonic currents is difficult to synthesize the curves of the instantaneous phase currents, which largely determine the choice of the parameters of converter and its energy performance.

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The admission about the infinitely large capacity filter capacitors provides approximate solution of the task at hand, because the output voltage ripple is heavily influenced by the input. Despite this, the analysis of electromagnetic processes in the simplest case, when the input voltage of the inverter permanently, are an important first step in the development of sufficiently precise engineer Noah methodology. A powerful traction motor spinning quickly influence active resistances of its windings negligibly small. Constant time damping circuits currents in the windings of the motor virtually the entire range of operating frequencies (except the starting area until 10-15 Hz) is greater than the time between the current in the phase windings anchor; Therefore it is convenient to use a method based on the principle of permanence of magnetic circuits of the rotor. Repeated experimental studies on the stands and on locomotives showed good compliance of theoretical and experimental results. Using this principle, greatly simplifies the theoretical analysis. Full flux linkage phase of stator windings will present as a sum of an unchanging in time over the transition of magnetic and magnetic voltage dependent for over transition resistance $x'' = \omega_b \sigma L$. This is true for engines and asynchronous and synchronous. В верх переходному потокосцеплению соответствует сверх переходная E'' . Are formal variables substantially facilitating transient analysis, although they are not due to physically defined magnetic field. At the top of the transitional regime change point (E), for example when changing the stator current, maintain the previous value. Despite the fact that the work of the electric machine with thyristor inverter is a continuous cycle of transients, the value and direction of at the top of the economies in E on the vector diagram can be adopted unchanged. The relationship between e "primary harmonic component phase E1 and corner between them set of vector charts:

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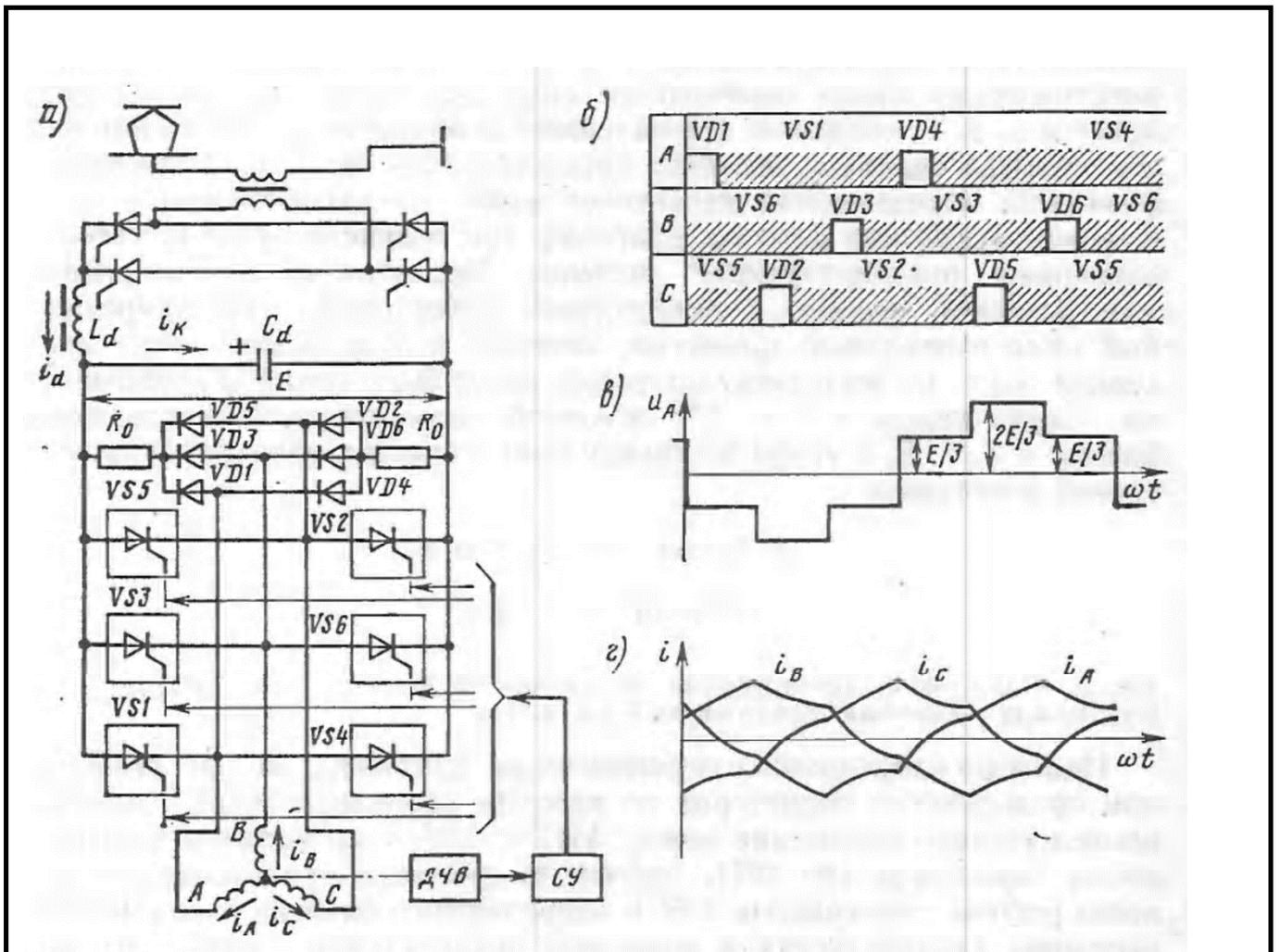


Figure. 4.5.3. Schematic diagram of frequency converter with auxiliary inverter voltage for powering the traction asynchronous motor (a) diagram electric valves (b), voltage and phase A(b) and phase currents (g)

$$E'' \cos \Delta\theta = E_1 - I_1 x'' \sin \varphi;$$

$$E'' \sin \Delta\theta = I_1 x'' \cos \varphi, \quad \text{where } I_1 \text{ is the basic harmonic component of phase stator currents; } \varphi - \text{ the angle between the main harmonics (E) and current.}$$

Voltage inverter with limited, for example, up to 120° intervals of thyristors conduction performance on takes an intermediate position between impulse voltage regulation and c thyristors conduction intervals 180°, and on the borders of existence, the mode of operation with an interval of 120° and continuous phase current characteristics and possible fractures are unstable; therefore practically apply mainly auxiliary inverter voltage conduction intervals 180°, the so-called auxiliary inverter voltage 180°- type. In this inverter for calculating the instantaneous (i) phase current (fig. 4.5.4)

when perfectly but smoothed input voltage and frequency of the engine is large enough to conveniently use the equation

$$i/I_1 = \sin(\omega t - \varphi) + \zeta I_{k*}$$

The relative value of the short-circuit current of the motor when the the corner frequency ω stator current $I_{k*} = U_1 / (x''_{l1})$, where U_1 is the main component of harmonic voltage.

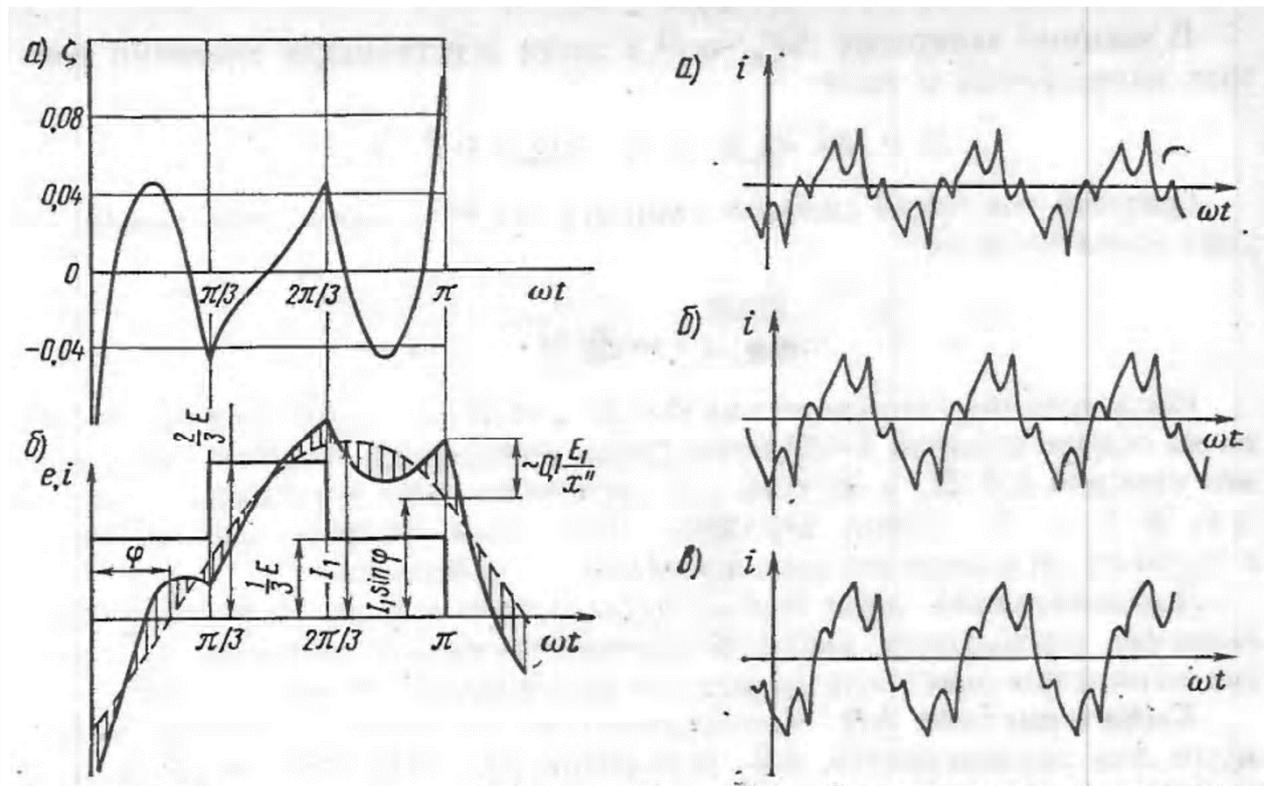


Fig. 4.5.5. Denigrated curve function (a) curve and better phase current (b) asynchronous motor from auxiliary inverter voltage types of 180°

Figure. 4.6. the pilot phase of the traction current curves asynchronous motor capacity 900 kW at $M = 0,5 M_f$ (a), $M = M_f$ (b) и $M=1,25 M_f$ (v) Experimental data (fig. 2.9) are in good agreement with the theoretical description of the shape curves phase current. The inverter converts DC power into the energy of three-phase alternating current:

$$U_d I_d - \Delta P_H = 3U_1 I_1 \cos \varphi,$$

where U_d , I_d – voltage and input current of the inverter; U_1 , I_1 – voltage and output current of the inverter; $\Delta P_{\text{и}}$ – energy loss in the inverter. Additional losses could be taken into account in the steel engine. Saturation takes into account the choice of the corresponding value L^μ , other engine parameters depend on the saturation in small degree.

Characteristics of induction motor. You can get the Visual calculation formulas for asynchronous motor characteristics, limiting their flexibility and adopting $r_s = 0$, that does not make notable errors for powerful asynchronous motor when $f_s / f_{\text{snom}} > 0,3$. If necessary, the losses in the stator copper account for approximately, for example the relevant slide external characteristics of a rectifier. When approval $r_s = 0$ and taking into account the expressions for phase voltage U_1 and current I_1 can be written:

$$U_d = \frac{\pi^3}{3} I_d f_s \frac{\sigma L_s}{1 - \sigma} \left(\frac{f_r}{f_{r \text{ КР}}} + \frac{f_r \text{ КР}}{f_r} \right);$$

$$M = \frac{\pi}{12} p_{\text{п}} \frac{I_d^2 r_r'}{f_r} \left(\frac{L_s}{L_\mu} \right)^2 \left(1 + \frac{f_r^2}{f_{r \text{ КР}}^2} \right).$$

Dependence of U_d (I_d) set the traction Rectifier; in the presence of the condenser filter it differs from the external characteristics of rectifier on a traditional e. p. Rectifier type with reservoir traction engines. External characteristics of U_d (I_d) rectifier with output inductive-capacitive filter (fig. 4.7), has a flat part, when rectified current is continuous, and steeply falling part of discontinuous current erect. Flat part of external characteristics are calculated the same way as is done for traditional ER .Rectifier type because the ripple current in smooth reactor are practically the same. When you see the intermittent current in the load average voltage to the condenser filter increases sharply until the amplitude value of the U_m secondary voltage power transformer. Even more distorted input characteristics of single-phase inverter in energy recovery mode in the power network. For small values of the rectified DC voltage othe capacitor is zero, because it shunted reverse current diodes voltage

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Figure. 4.8. external characteristics of single-phase rectifier requires large reactors (top) and the input characteristics of single-phase inverter (bottom) with inductive capacitive filter the ripple current. The smoothness of a rectified current, i.e. the magnitude of the ripple current rectified in *sглаživaûšem* reactor and rectified voltage to the condenser filter is determined from techno-economic considerations. Relative ripple current is usually at the level of $\pm 25\text{--}30\%$.

Voltage pulsation auxiliary inverter voltage led thus to the formation of additional turning or braking points. There may be an effect of stabilizing or destabilizing the regime, by contrast, work, defined the basic harmonic voltage component. Amplitude v -x harmonics phase current is determined by the v -harmonics linear voltage and frequency impedance of hell on the harmonica. Therefore, the most significant and relevant currents become threads in small ' and especially when , $v = 0$, when a permanent component of the phase current is limited to only live ohmic resistance and losses in the inverter and connecting the wires.

Small air gap from asynchronous motor in combination with low ohmic resistance phase windings with a small air gap of the stator, significantly exceeding the small rotor air gap, make powerful traction asynchronous motor vulnerable to low-frequency harmonic voltage. Calculations showed that a permanent component of the phase current at $f_1 = 100$ Hz rectified voltage stabilization accuracy on the condenser filter must be less 2 %; almost same with inductive-capacitive filter the amplitude of pulsation $U_p = (0,05\text{--}0,1) U_d$. The amplitude of the harmonics of output voltages form

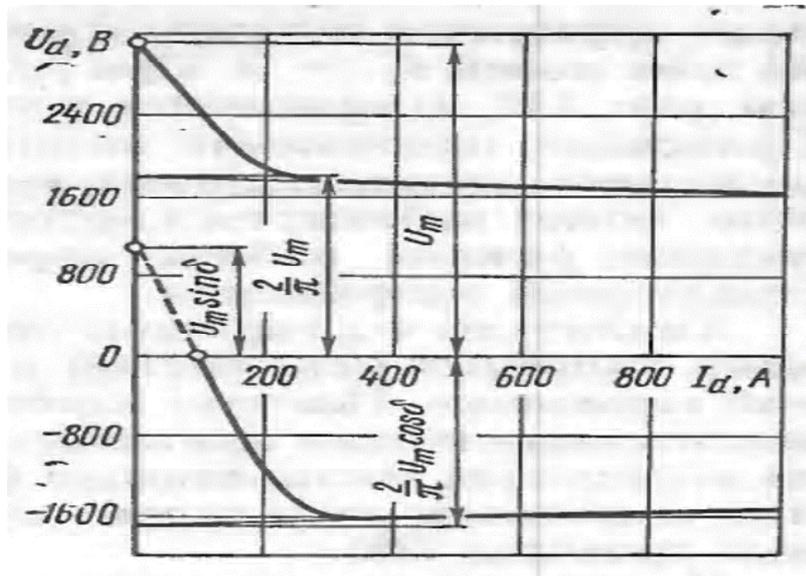
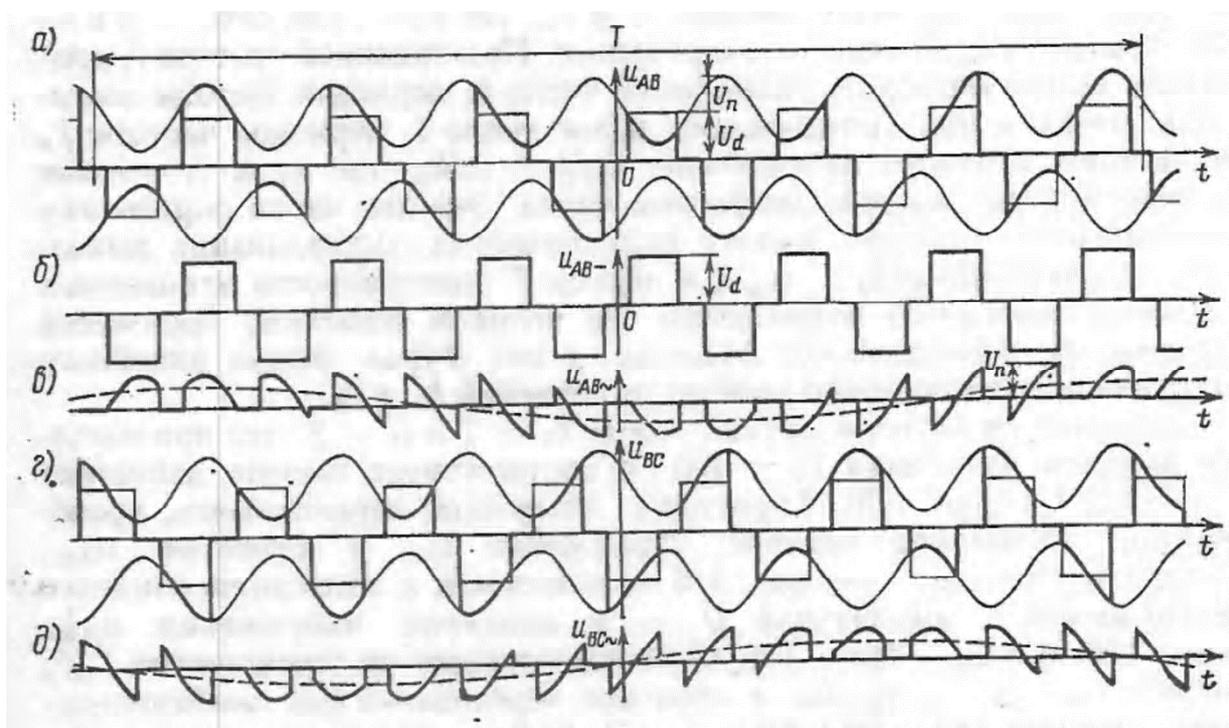


Fig. 4.8



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4.9. Time diagrams the instantaneous linear voltage u_{AB} (а) и u_{BC} (г) asynchronous motor and its components from a constant input voltage inverter for line voltage (б)

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short circuit inductances hell relevant slip equal to unit)

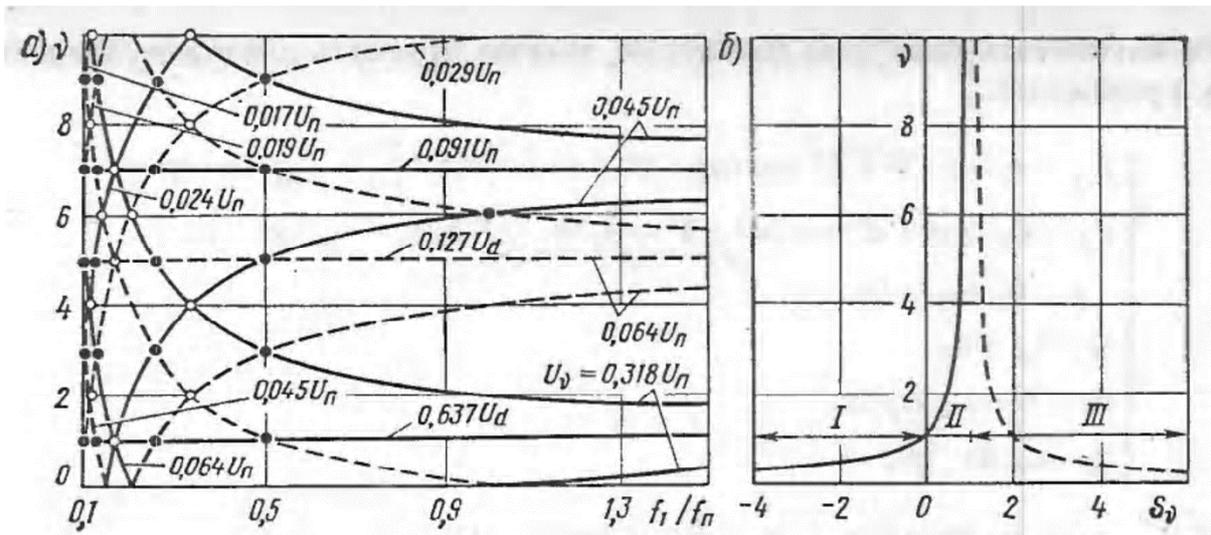


Fig. 4.10. Order dependencies and their corresponding harmonics amplitude with direct (solid lines) and reverse alteration phases of relative frequency of the engine (s), slip the rotor (b) modes: 1-2: turbine-engine; 3-brake infinite divergent series, therefore, for analytically determining the amplitude of pulsation U_n use substitution scheme with top transitional inductances $L'' = \sigma L_s$ (short circuit inductances hell relevant slip equal to unit).

Ripple voltage. How did reflected reduced capacitance filter on system properties of auxiliary inverter voltage- asynchronous motor? For greater visibility will not take into account the rectifier input voltage pulsation characteristic of ER AC. All active resistors in the power scheme does not take into account. This is valid because we are talking about the power of the engine capacity of around 1000 kW, which is not below which is not below 90—95 %, working range of frequencies from approximately 10 up to 140 Hz.

Introduction a fictitious E excitation (E) to Hell is a convenient hack allows you to tie together the motors synchronous and asynchronous types. Mock direction vector (E) on a vector chart of hell in principle can be arbitrary, since it is only for fixing points open thyristors and the provisions of the main harmonic voltage vectors E1 and phase at the top of the economies in E ''.

Input current of inverter in a time interval is determined by the current i_B phase B.

In accordance with the relevant equations for phase voltages e_A, e_B, e_C , arising from the principle of permanence of magnetic-magnetic motor circuits, you can write the following system of equations:

$$\begin{cases} e_A - e_C = -\sqrt{3} E'' \cos(\omega t + \theta'' + \pi/3) + L'' d(i_C - i_A)/dt = 0; \\ e_A - e_B = \sqrt{3} E'' \cos(\omega t + \theta'' - \pi/3) - L'' d(i_A - i_B)/dt = u_d; \\ i_A + i_B + i_C = 0; \\ i_d = i_B + i_k; \\ u_d = E - L_d di_d/dt; \\ i_k = C_d du_d/dt, \end{cases}$$

where θ – offset angle relative to the direction e E thread mutual induction or fictitious E excitation E_B i_k – filter capacitor current: E – power supply voltage, which is assumed to be constant.

This system of equations can be reduced to a single differential equation of order 3, binding input current auxiliary inverter voltage with the rest of the schema options:

$$\frac{d^3 i_B}{dt^3} + \frac{2L_d + 3L''}{3C_d L_d L''} \frac{di_B}{dt} = \frac{2E}{3C_d L_d L''} - \frac{1 - \omega^2 C_d L_d}{C_d L_d L''} E'' \cos\left(\omega t + \theta'' - \frac{\pi}{6}\right).$$

The main advantage of auxiliary inverter voltage is considered the lack of reactive energy exchange between the elements of the power circuits and switching capacitors. Practically this means that switching (thyristor power key locking time) currents in inductive smoothing reactor and motor phases, as well as the voltage to the condenser filter is not changed. Under (E) these boundary conditions are permanent integration.

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The average value of the input current of the inverter is determined by integrating the current in the phase in the time interval $-\beta_0 \leq \omega t \leq -\beta_0 + \pi/3$:

$$I = \frac{3}{2} a_1 \frac{E''}{\omega L''} \sin(\beta_0 - \theta'');$$

The first coefficient of the sine of a number of decomposition curve instantaneous voltage phase asynchronous motor gives the amplitude of the projection of the vector E_1 on the axle of a fictitious vector E_B excitation::

$$E_1 \cos \theta = a_1 E \cos \beta_0 + b_1 E'' \cos \theta''.$$

In this equation

$$b_1 = \frac{k^2 l}{2(k^2 - 1)(l + 1)} \left\{ 1 - \frac{3}{\pi(k^2 - 1)} \left[\frac{\sqrt{3}(k^2 + 1)}{2} + k \operatorname{ctg} \frac{k\pi}{6} \right] \right\}.$$

The first coefficient of the cosine series of Fourier decomposition is the projection of the vector amplitude E_1 on the axis perpendicular to the axis of the fictitious vector E_B

Therefore,

$$E_1 \sin \theta = a_1 E \sin \beta_0 + b_1 E'' \sin \theta''.$$

From well-known vector diagrams for harmonic current and voltage AC motor neâvnpolûsnogo should that $E_1 \sin \theta = E'' \sin \theta'' / (1 - \sigma)$ The joint solution of this equation and equation allows you to get the ratio

$$a = \frac{E}{E''} = \frac{\sin \theta''}{\sin \beta_0} \frac{1 - b_1(1 - \sigma)}{a_1(1 - \sigma)}.$$

We introduce the notation:

$$b = \frac{E_1 \cos \theta}{E''} = a_1 a \cos \beta_0 + b_1 \cos \theta''; \quad c = \frac{E_1 \sin \theta}{E''} = \frac{\sin \theta''}{1 - \sigma}.$$

Then you can write the following expressions: to determine the angle of the load of the engine, the angle between the main supply voltage and harmonic excitation (E

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$$\operatorname{tg} \theta = \frac{c}{b} = \frac{\sin \theta''}{(a_1 a \cos \beta_0 + b_1 \cos \theta'') (1 - \sigma)};$$

for the amplitude of the main harmonic component of phase voltage

$$d = E_1 / E = \sqrt{b^2 + c^2} / a.$$

and current three-phase short circuit through the bridge Rectifier and current three-phase short circuit through the bridge Rectifier

Angle between the main harmonic components of I1 and E1, voltage

$$\operatorname{tg} \varphi = \frac{3E_1^2}{2\omega L_s EI} - \operatorname{ctg} \theta = \frac{ad^2 \sigma}{a_1 \sin (\beta_0 - \theta'')} - \frac{b}{c}.$$

Analysis engine performance based on actual settings input filter voltage inverter is conveniently conducted in relative units, with reference, as with other types of analysis, such as engine valve, take the average converted E excitation $U_b = 3\sqrt{3} E_1 / \pi$ and current three-phase short circuit through the bridge rectifier $I_b = \pi E_B / (2\sqrt{3} \omega L_s)$.

The relative importance of the current engine is out of balance active energy

inverter $EI = \frac{3E_1 E_B}{2\omega L_1 \sin \theta}$ in the form of

$$I^* = \frac{I}{I_0} = \frac{3\sqrt{3} E_1 \sin \theta}{\pi E} = \frac{3\sqrt{3} c}{a} = \frac{3\sqrt{3} a_1 \sin \beta_0}{\pi [1 - b_1 (1 - \sigma)]}.$$

As you can see, it does not depend on the angle θ'' . From the same active energy balance is and the relative value of the voltage of the motor

$$E^* = \frac{E}{U_0} = \frac{\pi E_1 \sin \theta}{2\sqrt{3} I \omega L_s} = \frac{\pi}{3\sqrt{3}} \frac{\sigma \sin \theta''}{a_1 (1 - \sigma) \sin (\beta_0 - \theta'')}.$$

The relative torque $M^* = E^* I^*$.

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Analysis of properties of the engine it is convenient to maintain in the following order. If you know the parameters of the power scheme L_d, C_d, L'' known for its own angular frequency $\omega_0 = \sqrt{(1+1)/(C_d L_d)}$ and quantifies $l = 2L_d / (3L'')$. Other dimensionless coefficient $k = \omega_0 / \omega$ depends on the frequency of ω engine speed. In the initial stage of analysis this ratio are asking as a parameter and equations (74A) and (75) find the auxiliary winding and scattering coefficient values, i. e. the ratio at the top of the economies in inductance L'' engine to its synchronous inductance L_s , is in fairly narrow limits and can also be considered known.

Using the relationship between the values of E, E'', θ'' и l , You can build temporary diagrams for any operating mode the engine at different ratios of power settings schema. For example, fig. 4.13 are temporary chart currents and voltages

when $\beta_0 = 30^\circ;$
 $\sigma = 0,3; l = 10; \theta'' = 22^\circ, k = 5,$ When the engine near the resonant frequency of rotation, $\omega = \omega_0 / 6,$ When $s = 1.$

When you select C_d capacity filter capacitors should comply with the following condition:

$$\omega_0 = \sqrt{\frac{1}{C_d} \left(\frac{1}{L_d} + \frac{1}{1,5\sigma L_s} \right)} < (4 \div 5) \omega_{\min}$$

or

$$C_d > \frac{(1,6 \div 1,0) 10^{-3}}{f_{\min}^2} \left(\frac{1}{L_d} + \frac{2}{3\sigma L_s} \right).$$

The ER AC is also possible, but only in the transition to a fundamentally new rectifiers with schemes without the inductive output e.g. Pulse-based regulation in the rectifier. On the contrary, the inductance of short circuit of the engine, feeding from the A_{in} , from many points of view may be useful to have more, so on some foreign electric locomotives. Between the auxiliary voltage asynchronous motor and the inventor incorporated additional current-limiting reactors.

In this regard, the positive technical solution would be to synchronize the activities of multiple traction TEE with a fixed phase of mutual time-shifted and feeding them by generic filter. However, this is undesirable because of the necessity of individual starting frequency of each engine as unevenly distributed load between parallel engines, as well as due to needing a forced disconnection of one of the engines.

4.6. Modeling autonomous inverter voltage (AIV)

With pulse-width modulation (PWM) sequence and moments of toggle keys for three-phase bridge inverter, defined equality instant voltage setting and the carrier frequency (fig. 1). Energized setting frequency refers to the three-phase sinusoidal voltage, frequency, which is equal to the output frequency inverter f_{ex} . A carrier frequency voltage F_H Pilo is shaped. The ratio of the amplitudes of the sets and saw-shaped stress is called modulation factor k_M . When $k < 10$ stand-alone inverter voltage (AIV) operates in PWM mode. Combinations open (1) and closed (0) keys if AIV 180° management are listed in the table. 1. These combinations can be represented as binary codes that represent decimal numbers. These numbers for all 60° zones are

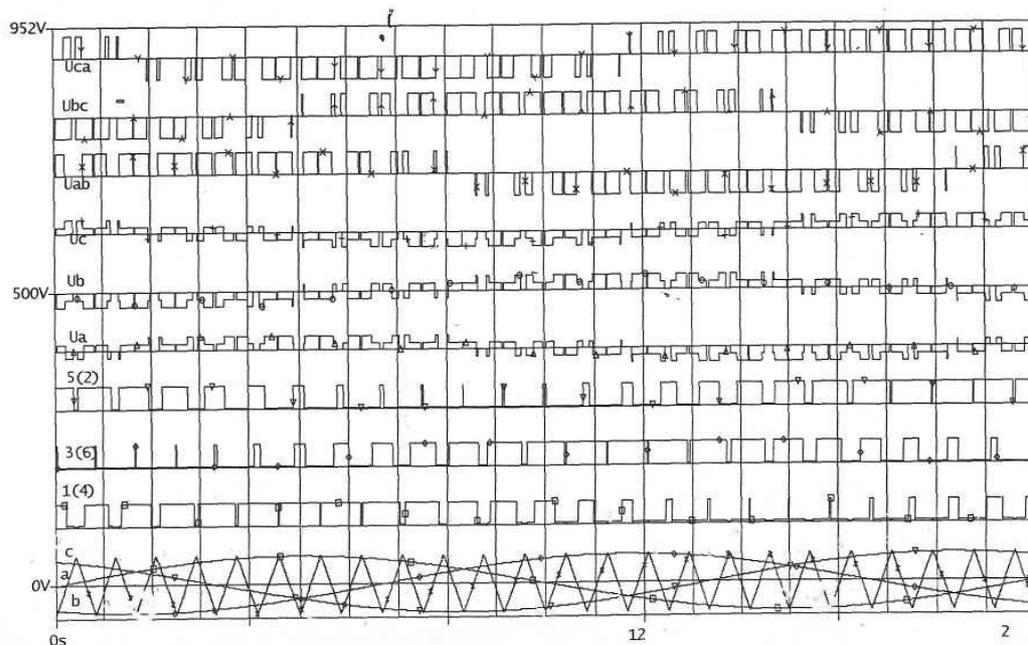


Figure. 4.1. three-phase Waveform voltage frequency 50 Hz sets (a, b, c) stresses on the AIV keys (1 (4), 3 (6), 5 (2)), phase (U_a U_b U_c) and linear (U_{ab} U_{ac} U_{ca}) AIN in carrier frequency voltages $F_H = 1200$ Hz modulation factor $k_M = 1$ кратными числу $7=2^2+2^1+2^0$.

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For more compact record divide these decimal numbers at 7 and the values will be called decimal codes.

To avoid the possibility of a short circuit at the input to the inverter it is necessary between switching pause when open only two semiconductors. To do this, you must open another key with a delay of 5-10, after the previous locking. PWM control algorithm for creating pauses are additional two States. The opening of all the odd keys inverter complies with the binary or decimal 010101 $2^1 = 2 + 1$. The opening of all the even-numbered keys correspond to binary or decimal number 101010 = $2^2 + 2^4 + 2^6$. When you divide those numbers to get 7 decimal codes respectively 3 and 6.

Table 4.1 work order keys if AIV 180° control algori

Interval	Operation transistors						Binary code	Decimal number /code
	VT6 $2^5=32$	VT5 $2^4=16$	VT4 $2^3=8$	VT3 $2^2=4$	VT2 $2^1=2$	VT1 $2^0=1$		
0° - 60°	1	1	0	0	0	1	110001	49 / 7
60° - 120°	1	0	0	0	1	1	100011	35 / 5
120°-180°	0	0	0	1	1	1	000111	7 / 1
180°-240°	0	0	1	1	1	0	001110	14 / 2
240°-300°	0	1	1	1	0	0	011100	28 / 4
300°-360°	1	1	1	0	0	0	111000	56 / 8

PWM is implemented by interleaving public key combinations that you can denote a sequence of decimal codes 3 a b 6 (b) (a), 3 (a) (b) (b) 6 a. ... The values of variables a and b vary in each 60° zone in accordance with fig. 4.2. The number of combinations of 3 a b 6 b and within each 60° zone is determined by the ratio of carrier and output frequencies.

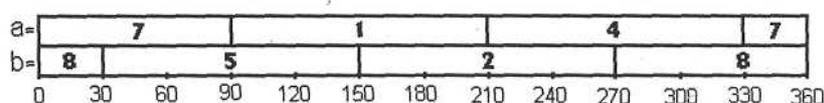


Figure. 4.2. PWM timing

In Figure 4.3 shows a block diagram of the implementation of the proposed ways to form software PWM.

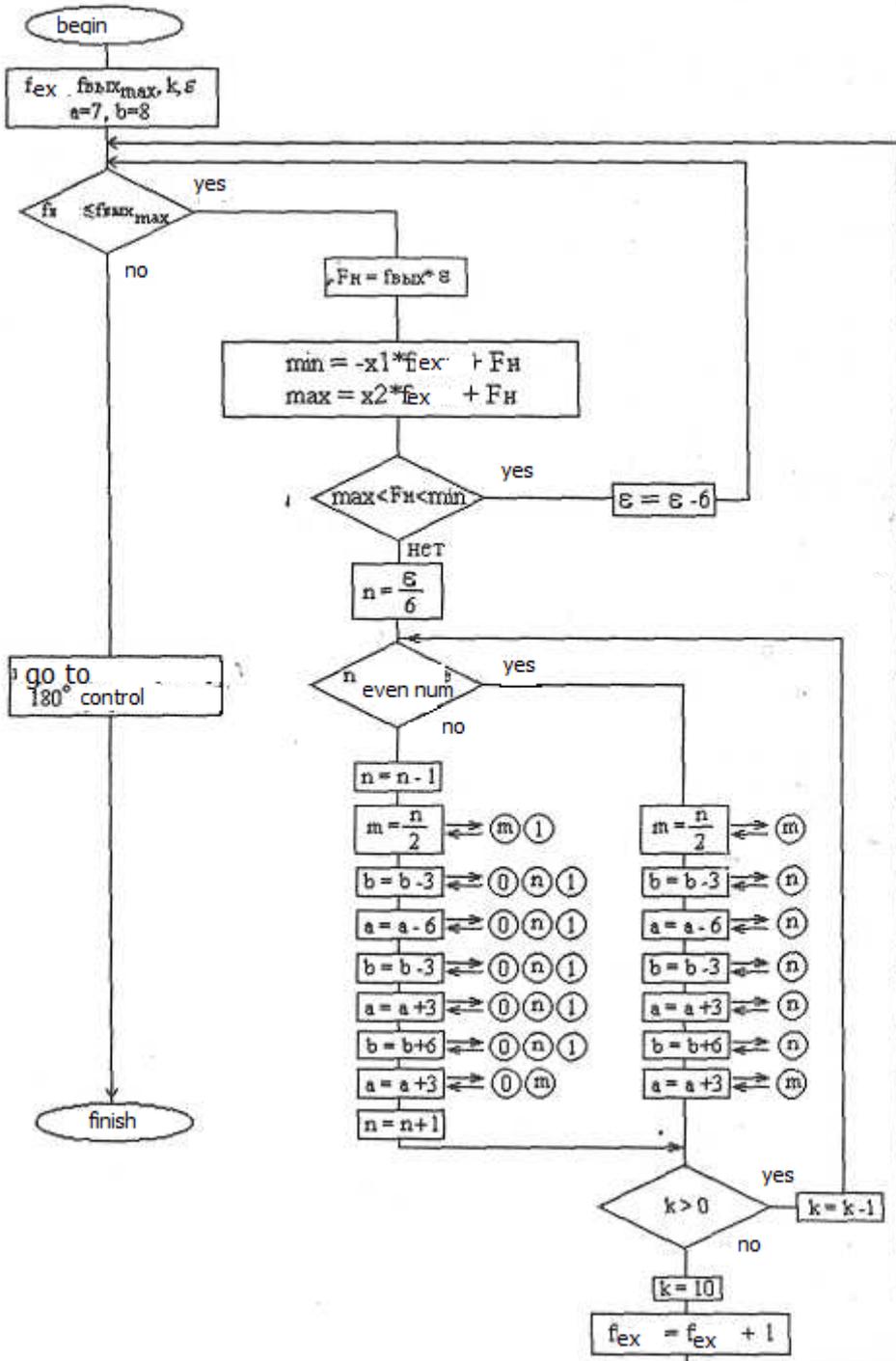
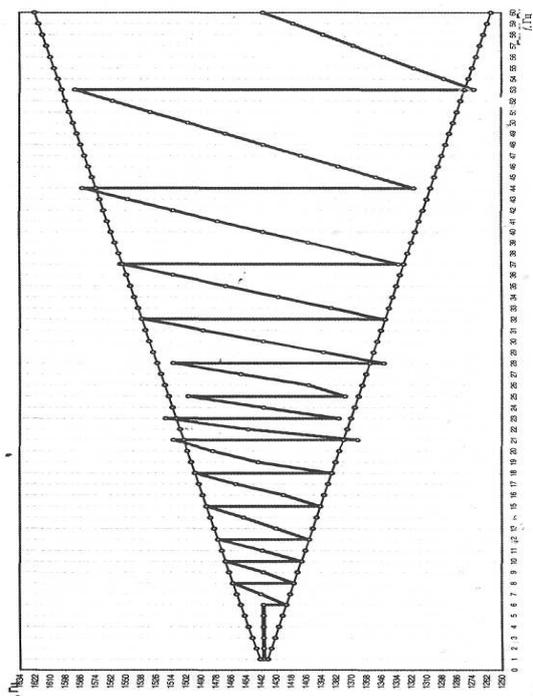


Figure. 4.3. Flowchart program execution to control algorithm pulse-width modulation.

At the beginning of the algorithm values are set: the current output frequency inverter f_{ex} , maximum output frequency $-f_{ex(max)}$, multiplicity carrier and output

frequencies - ϵ , number of output frequency periods, passing at a constant frequency of multiplicity $\epsilon - K$, the initial values of variables and $a = 7$ and $b = 8$, defining the status of key elements in the first 30° . The expression $\min(f_{ex})$ and $\max(f_{ex})$ are the equations of straight, limiting the value of the carrier frequency, where X_1 and x_2 rates under the terms of the predefined starting asynchronous drive embodied in the algorithm in the form of ready-made values. In Figure 4.4 shows an example of this dependence. Condition that the value of the carrier frequency is in the range between \min and \max . If F_H goes over the limit, then the multiplicity is reduced by pole b ($e = \epsilon - 6$) and the cycle repeats until the value of the carrier frequency reaches the desired interval.

If F_H in this range, then determines the number of periods per carrier 60° output frequency - $n = e/6$. Based on the results of the determination of the number of periods you decide on the work of the control algorithm with even or odd PWM. To generate a sequence of impulses is 29 routines that display in the microcontroller port a specific sequence of pulses. Subprogramme №0 и №1 display port 6 sequence, respectively, (b) and (c), 3 (a), (b), where a and b variables displays the values assigned to them at the moment. All other output routines in the port sequence 3, a, b, 6, b, a certain number of times.



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Fig. 4.4. Diagram of dependence of the carrier frequency of the output, with the limitation of the possible values of the carrier frequency.

To refer to subroutines used link from returning. For even a PWM with the purpose of treatment to different subprogrammes used variables n and m with a link is made to the subroutine, which at the moment is equal to the variable n, or m. First sub №0, then the subprogramme with the number, which at the moment is equal to the variable n, and then sub №1. The algorithm then returns to the same step that was referenced. In moments of implementation of subprogrammes formed key management signals AIN. The developed method of formation of the software PWM control algorithm, taking into account the switching between pauses, replaces the traditional formation of analog or PWM control algorithms tabular way, and also allows you to reduce the memory footprint management program and increase the speed of its execution. When you move from one zone to another sequence of operations remains unchanged, that simplifies the software implementation and thus improve the reliability and performance of control systems of AIV.

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5. The economic part

This research project addresses the calculation of electrical locomotives with asynchronous AC traction drive. The hardware taken standard (IGBT modules and drivers of Toshiba, FUJI Electric, Mitsubishi and Eupec, asynchronous traction motor type-124 d t). Modern electronic equipment manufacturers offer a wide variety of semiconductor elements and the class and costs. Correct elections IGBT modules for inverter rectifier installation, you can achieve the optimum economic benefits, while maintaining the reliability of the system.

This section examines the economic reliability of semiconductor converters. With the increase in the reliability of their cost increases substantially. Equipment operating costs lower than it is more reliable.

To assess the impact of economic indicators on system reliability use operating cost ratio:

$$K_{c.э.} = \frac{C_{main}}{C_{manuf}} \quad (5.1)$$

where C_{main} – the cost of maintenance of the system;

C_{manuf} - the cost of manufacturing system;

Calculation will be separately for inverter and rectifier because the requirement for different elements. The cost of manufacturing system consists of the costs of acquisition and cost of semiconductor elements for installation:

$$C_{manuf} = C_s + C_m \quad (5.2)$$

where C_s – the cost of semiconductor elements is defined as the product of the number of elements per unit cost, sum.

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проверил		Шадмонходжаев								
Зав.каф		Бредиев У.Т.			ТошТЙМИ “ЭТ ва ЮТЭЙТ”					

$$C_s = N_{эл} \cdot C_{эл} \quad (5.3)$$

C_m - cost of erecting work items, 20% of the cost of semiconductor elements:

$$C_m = 0,2 \cdot C_s$$

Converters based on power semiconductor devices such as IGBT transistors require virtually no services. Only it is necessary to periodically change items out of order. And so, the cost of operation consists of the costs of acquiring new items in place of broken-down and dismantling costs.

$$C_{main} = C_{re} + C_{removing} \quad (5.5)$$

Where C_{re} - cost of replaced elements;

$C_{removing}$ - dismantling costs, new items, 25% from the cost of replacement elements.

Cost of replaced elements is defined by the formula

$$C_{re} = N \cdot (1-P) \cdot C_{эл} \quad (5.6)$$

where P – reliability of the converter, after a period of time (accept $T=10\ 000$ ч.).

5.1. Economic indicators of reliability of inverter.

GBT inverter design modules are presented in table 5.1.

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Manufacturer	type	Class	Cost per unit $C_{эл.,}$ sum.	The number of elements of the converter N, ps	The cost of the converter, sum. C_{inv} sum.	Reliability after 10000 h. work P
FUJI Electric	1MBI100L-060	6	125707	162	2036466	8,2E-06
	EVL32-060D	6	136927	126	17252800	0,00023
	2DI200MC-050	6	206494	90	1888267	0,005862
	1DI400A-060	6	184851	54	9981978	0,120931
	2DI100D-100	10	205390	108	22182174	0,000686
	1DI200Z-100	10	188959	60	11337555	0,045822
	1DI400D-100	10	358925	28	10049911	0,509304
Eupec	DD600S16K4	16	64355	18	11584024	0,645143
Mitsubishi Electric	CM800HA-34H	17	736976	18	13265576	0,86217

For economic calculation select from each class for one type of semiconductor devices, which is more reliable than other elements of the same class (calculation of reliability is given in section 2.4). Table 5.2.

Manufacturer	Type	Class	The cost of the converter, sum C_{inv} sum	Installation works (20 %) C_m sum.	The cost of manufacturing C_{manuf} sum	Reliability after 10000 h. work P
FUJI Electric	1DI400A-060	6	9981978	1996395	1197802	0,12
	1DI400D-100	10	10049911	2009955	12059867	0,51
Eupec	DD600S16K4	16	11584024	2316804	13900829	0,645
Mitsubishi	CM800HA-34H	17	13265576	26767	15918691	0,862

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Suppose that after 10000 hours of those parts of the items that you specify in the column of reliability remain workability, and the remaining elements will break down.

The results of the calculations are shown in table 5.3.

are shown in Figure 5.3.

Table 5.3.

Type	Cost per unit $C_{эл.,}$ sum.	The number of elements of the converter N, ps.	The likelihood of a bounce after 10000 h. work(1-P)	The number of replaceable elements Nre, ps.	Cost of replaced elements C_{re} sum.	The cost of dismantling works $C_{removing}$ sum.	the cost of operation, _{main,} sum.
1DI400A-060	184851	54	0,88	48	8872869	2218217	1109108,7
1DI400D-100	358925	28	0,49	14	024955	1255385,7	6281194
DD600S16K4	643556	18	0,355	7	4504898	126202	5631100
CM800HA-34H	736976	18	0,138	3	2210929	552732,3	2763628,6

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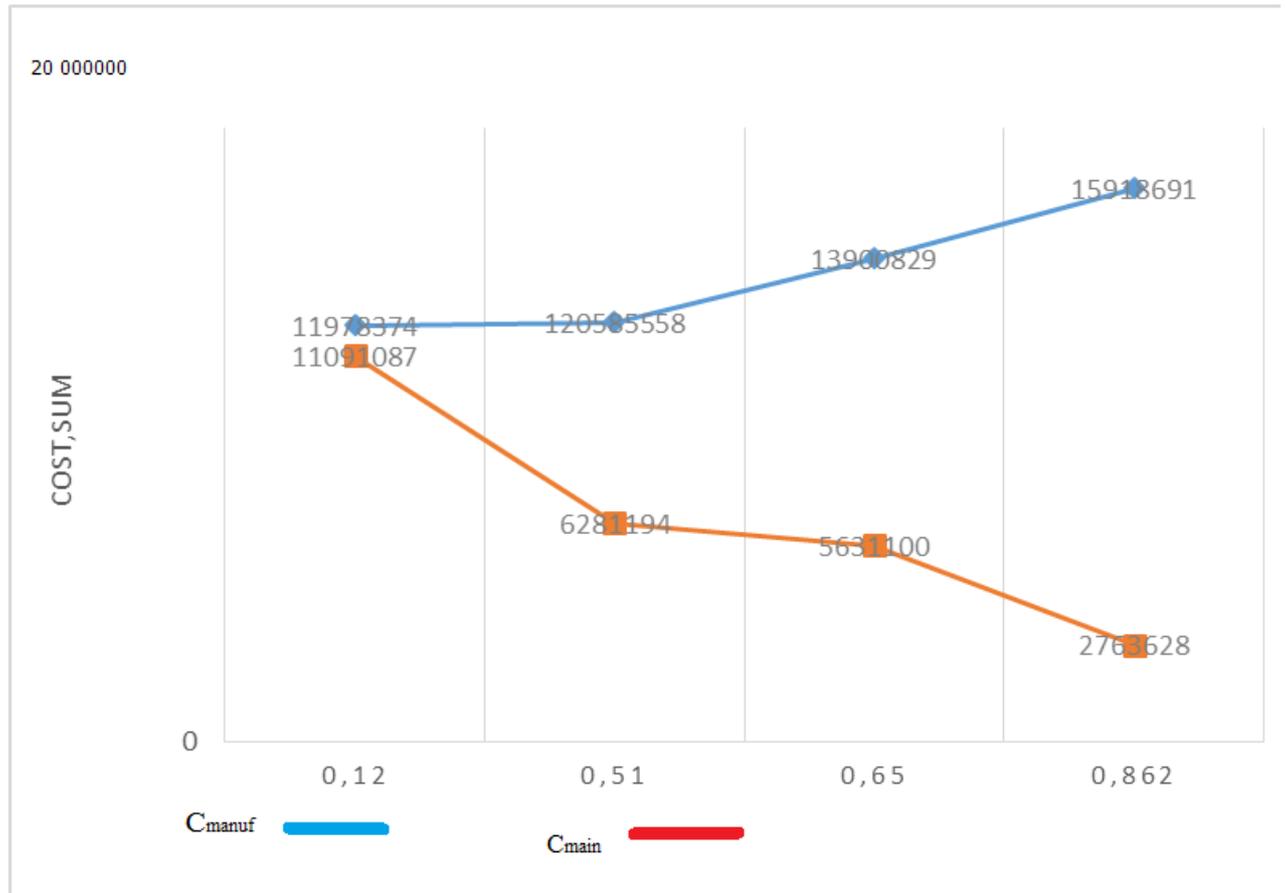


Figure 4.1. Economic indicators of reliability of the inverter.

In many cases, it is advantageous to choose equipment based on the following criteria: $C_{main} + C_{manu} = C_{min}$

Table 5.4

Type	The cost of maintenance C_{main} sum.	The cost of manufacturing C_{manu} sum.	Sum of values Sum of values $C_{main} + C_{manu}$ sum.	Operating cost ratio $K_{c.э}$
1DI400A-060	11091087	11978373	23069460	0,926

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1DI400D-100	6281194	12059867,6	18341062	0,5
DD600S16K4	5631100,8	13900829	19531929,8	0,4
CM800HA-34H	2763628,6	15918691	18682316,8	0,174

4. 2. Economic performance reliability of Rectifier.

IGBT inverter design modules are present in table 5.5

Table 5.5

Manufacturer	Type	Class	Cost per unit $C_{эл.,}$ sum	The number of elements of the converter N, ps	The cost of the converter, sum C_{inv}	Reliability after 10000 h. work P
FUJI Electric	2DI200MC-050	6	206494	144	29735244	3,64E-05
	1DI400A-060	6	184851	80	14788116	0,011781
	1DI200Z-100	10	188959	108	20407600	0,000686
	1DI400D-100	10	270585	60	16235125	0,045822
Eupec	DD600S16K4	16	537548	32	17201564	0,297909
Mitsubishi Electric	CM800HA-34H	17	735783	24	17687434	0,509304
Toshiba	MG1500FXF1US51	34	1154162	12	184666593	0,925478

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Economic calculation of reliability of the rectifier is similar with inverter. The calculation results are presented below in tables 5.6, 5.7, 5.8, and the schedule of economic indicator of reliability in Fig. 5.2.

Table 5.6

Manufacturer	Type	Class	The cost of the converter, руб. C_{inv}	Installation works (20 %) C_m sum.	The cost of manufacturing C_{manuf}	Reliability after 10000 hour work P
FUJI Electric	1DI400A-060	6	14791649	2957623	17745739	0,011781
	1DI400D-100	10	16235125	3247025	19482150	0,045822
Eupec	DD600S16K4	16	17201564,8	3440312	20641877	0,297909
Mitsubishi Electric	CM800HA-34H	17	17687434	3537486	21224921	0,509304
Toshiba	MG1500FX F1US51	34	18466593	3693318	22159912	0,925478

Economic calculation of reliability of the rectifier is similar with inverter. The calculation results are presented below in tables 5.6, 5.7, 5.8, and the schedule of economic indicator of reliability in Fig. 5.2.

Table 5.6

Manufacturer	Type	Class	The cost of the converter, sum. C_{inv}	Installation works (20 %) C_m sum.	The cost of manufacturing C_{manuf}	Reliability after 10000 hour work P
FUJI Electric	1DI400A-060	6	14791649	2957623	17745739	0,011781
	1DI400D-100	10	16235125	3247025	19482150	0,045822
Eupec	DD600S16K4	16	17201564,8	3440312	20641877	0,297909
Mitsubishi Electric	CM800HA-34H	17	17687434	3537486	21224921	0,509304
Toshiba	MG1500FX F1US51	34	18466593	3693318	22159912	0,925478

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Type	Cost per unit $C_{эл.}$ sum	The number of elements of the converter N, ps	The number of elements after 10000 h of operation (1-P)	The number of replaceable elements N _{re} , ps	Cost of replaced elements C_{re} sum.	The cost of dismantling works $C_{repairing}$ sum	operating cost, C_{main} sum
1DI400 A-060	184851	80	0,988219	79	14600264	3650783	11091087
1DI400 D-100	270585	60	0,954178	57	15423368	3855820	6281194
DD600 S16K4	537548	32	0,702091	22	11826075	2956518	56531100
CM800 HA- 34H	736976	24	0,490696	12	8843717	2210929	2763628
MG150 OFXF1U S51	115416 2	16	0,074522	1	1154162	12744384 0	1442724

Table 5.7

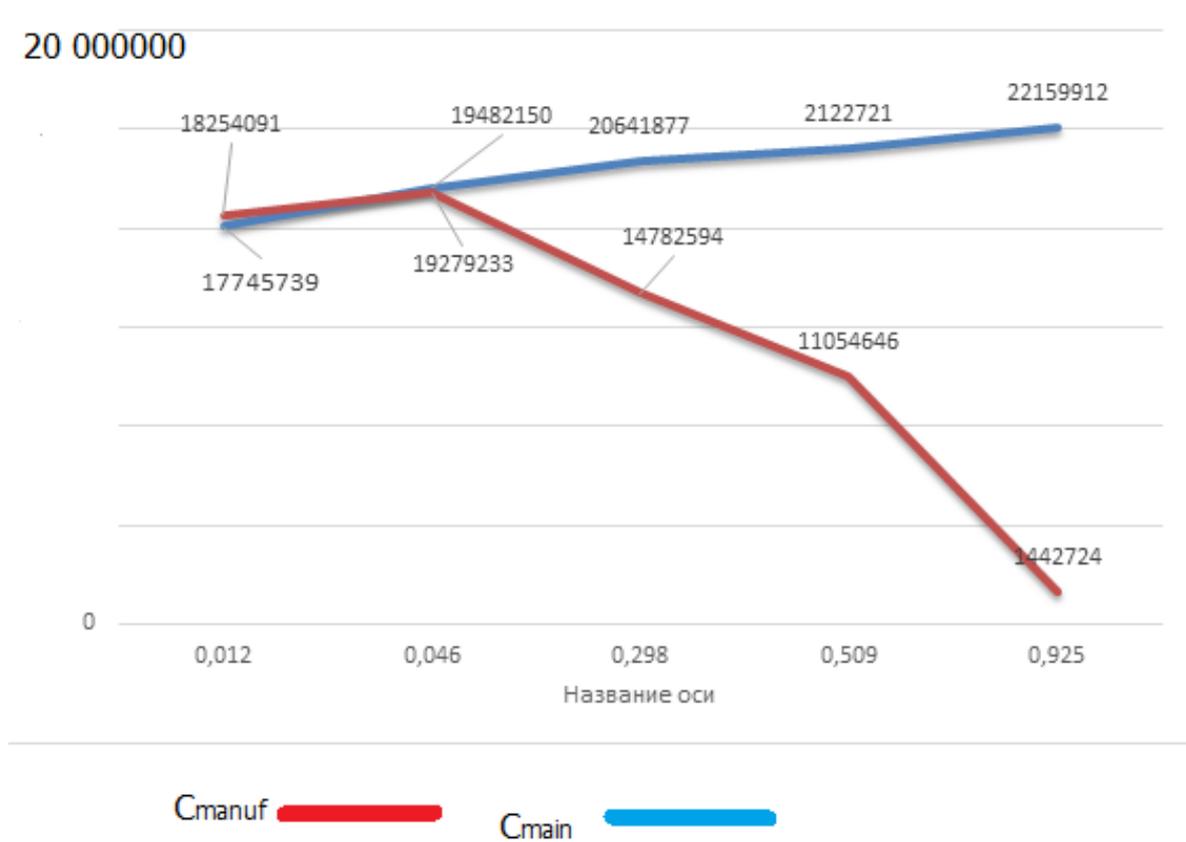


Figure 5.2. Economic indicators of reliability of the rectifier.

Table 5.8

Тип	operating cost, C_{main} ,	The cost of manufacturing	Sum of values $C_3 + C_{и}$	Operating cost ratio
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	sum	C_{manuf}	sum	$K_{\text{с.э}}$
1DI400A-060	1109108	11978373	13087481	1,028646
1DI400D-100	6294445	12059867	18354312	0,989583
DD600S16K4	5631100	13900829	195312929	0,716146
CM800HA-34H	2763628	15912691	18676319	0,520833
MG1500FXF1US51	1442724	22159912	23602636	0,065104

Conclusions estimates indicate that converters consisting of high-end semiconductor despite their value, more profitable at the expense of service. In converters with elements of low class number of devices is very high. In such a case, the multiplicity of redundancy is reduced, and the likelihood of failures increases. Operating cost ratio indicators shows that exploit high-end semiconductor devices several times more profitable ones, nevertheless, more reliable.

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6. Occupational health

6.1. Electrical safety unipolar touch in electrical installations up to 1000 V

In the railway transport not pulling power consumers from District step-down substations, tractive substations of electrified railways or from complete transformer substations. But regardless of the power supply secondary network substation voltage up to 1000 in the current rules of electrical devices perform under the scheme with isolated or earthed neutral. People might be energized as a result of touching either directly to the live parts (so-called normal mode of electrical installations), or to the body, which happened circuit current-carrying parts (so-called emergency operation mode of electrical installations). While in normal operation electrical installations and two monopolar might touch the person. When the bipolar touch exodus defeat is determined only by the magnitude of the voltage. When the unipolar touch hazard of electrical shock varies and depends on the electrical installation is grounded or isolated neutral.

6.2. Network with insulated neutral. When human touch to monopolar insulated neutral phase (fig. 6.1) amount of current through the human body can be found from the expression (6.1) where U -phase voltage of the network; G -conductivity of the human body; G_1, g_2, g_3 -active components phase isolation conduction; C_1, C_2, C_3, C -phase capacity relative to the ground, due to the almost identical length of individual phases wires take when calculating equal; g -phase multiplier. From the expression (6.1) shows that the current flowing through the human body depends largely upon the network isolation status. Consider the relationship network isolation parameters with impermeable currents corresponding to varying probabilities of freeing man from contact with powered parts. Taking $c = 0$ from the equation (6.1)

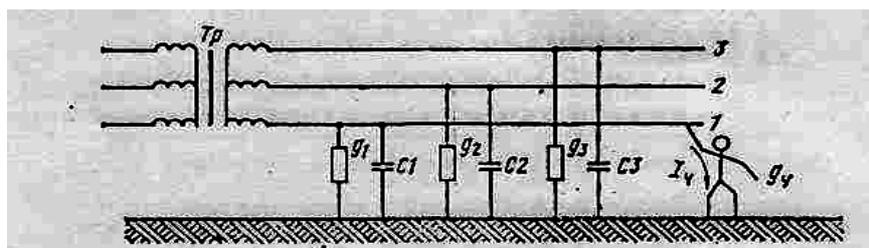
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$$g_2^2(A_2^2 - 1) + g^2[2A_2^2(g_1 + g_2 + g_4) - g_3] + A_2^2(g_1 + g_2 + g_4)^2 - g_3^2 = 0 \quad (6.2)$$

$$A_2 = \frac{I_y}{\sqrt{3}Ug_x}$$

On this equation were calculated ratio between the conductivities, respectively network g_1 , g_2 and g_3 with a current through the human body, equal to 6; 15 and 22ma, which corresponds to the probability of releasing 99.5; 50 and 0.5% for rice. 5.2 show the ratio between g_2 and g_3 conductivities, respectively with a current through the human body $I_p = 6$ Ma for networks with a voltage of 120; 220 and 380 v. Analysis of the curves shows that for a network with capacity $c = 0$ is characterized by the following: conductivity isolation phase, which concerns the people, had little effect on the ratio of the conductivities other phases; When fixed conductivity phase, which concerns the person, the amount of the conductivities of the two other phases varies slightly. Similar results were obtained when current through a person in 15 and 22 MA. Considering touch to any phase of the network, received equal odds of breaking the total insulation resistance network (table 5.1) corresponding to the different probabilities of independent human Liberation.

The current state of network insulation resistance check insulation control devices (COE) that show the total insulation resistance network. In addition to active resistance, network isolation on the amount of current through the human body



influence and network capacity, which cable networks can be significant.

Fig. 6.1 equivalent circuit of single-phase human touch to Seth with insulated neutral					ЛИСТ
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$$(6.1) \text{ taking } g_1 = g_2 = g_3 = 1/R_{iz}, \text{ you can get: } C = \sqrt{\frac{I_h^2 R_{ua} (R_{ua} + 6R_x) - 9(U^2 - I_h^2 R_h^2)}{9\omega^2 R_{iz}^2 (U^2 - I_h^2 R_h^2)}}$$

Where is the R_{a3} -active insulation resistance phase in relation to the Earth.

6.3 presents the characteristic of dependencies between capacity and network isolation resistance at a constant value of current passing through man. Taking $R_{U3} \infty$ conditions of electrical safety. In the table. 6.2 presents the critical capacity for 120 voltage networks; 220 and 380 v and varying probability of releasing. Similar calculations were

carried out for single-phase networks with insulated neutral, which are used to supply consumers with power up to 10 kW * A

Table 6.1

Critical resistance network isolation depending on mains voltage and likelihood of freeing

The likelihood of releasing%	Critical total insulation resistance network com on mains voltages,		
	120	220	380
99,5	25	45	80
50	10	19	33
0,5	6,5	12	20

Table 6.2

Critical network capacity depending on the mains voltage and the probability of freeing

The likelihood of releasing%	Critical network capacity, MKF, with mains voltages,		
	120	220	380
99,5	0,05	0,03	0,015

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50	0,13	0,07	0,04
0,5	0,2	0,1	0,06

The calculated expression for such a network is as follows: $R_2 = \frac{R_1(U - I_q R)}{I_h(R_1 + R_2)}$,

$$C = \sqrt{\frac{I_q^2 R (R_i + 4R_q) - (U^2 - 4I_h^2 R_h^2)}{\omega^2 R_i^2 (U^2 - 4I_h^2 R_h^2)}}$$

where R1 R2-phase resistance in relation to the Earth, in the particular case of R1 = R2 = Riz; Rh-resistance of the human body, taken to be equal to 1000 Om. The results of the calculations are presented in table 2. 5.1 and 5.2

Table 6.3

Critical total insulation resistance single-phase network with insulated neutral

The probability of release. %	The critical insulation resistance network, com on mains voltages. In		
	120	220	380
99,5	19	35	62
50	7	13	24
0,5	4,5	9	16

Table 6.4

Critical capacity single-phase network with insulated neutral

The probability of	Critical network capacity, MKF, with mains voltages in the
--------------------	--

release. %	120	220	380
99,5	0,16	0,086	0,05
50	0,4	0,2	0,125
0,5	0,62	0,32	0,18

Experimental research of isolation parameters networks showed that depending on the technological process of the production of insulation resistance and capacitance networks have a variety of sizes. In many cases, resistance and capacity contours more critical values for the corresponding parameters of the network even when the probability of release 0.5%, it should be borne in mind when drafting or other technical means to protect the person from electric shock.

Network with grounded neutral. In a network with earthed neutral point of neutral secondary winding is connected to the Earth lead, whose flowing resistance R_0 is not greater than 10 Ohm Then human touch for single-phase current through it

$$I_h = \frac{U}{R_h + R_0 + R}$$

where R is the resistance of a human with legs spread; $R = 3/2 (r\text{-soil resistivity, ohm-m})$. In the worst case, when $r = 0$, i. e. man stands on a conductive surface (metal, related to land), current through the human body $I_h = \frac{U}{R_h + R_0}$

Thus, human touch to the monopolar phase networks with insulated or grounded neutral represents a great danger for humans and requires additional technical resources , improve conditions of electrical safety in the operation of electrical equipment.

Conclusion.

To improve the efficiency of the electric whole VNA modern railways it is advisable to use new solutions electro whole management systems developed by Siemens, Toshiba, Alstom etc., using asynchronous traction engines, converters in GTO thyristors, in particular 4q-S inverter and voltage inverters. In this regard, on the basis of tender locomotives were purchased in Chinese electric locomotive build plant, on the draft by Toshiba .Choose locomotive :

- the possibility of recovery-acceptable conditions of warranty service-lower price compared to other manufacturers. Exploring 4q-S converter, account was taken of the development made in foreign applicants, masters, candidates of technical sciences and doctors from Europe and East Asia. 4q-S converter allows the use of regenerative braking. This work investigated the processes of regulation of frequency and voltage on an asynchronous traction motor. Performance of 4q-S and AIN converter analysed for models in MathLab.

Economic calculations showed that the more expensive items in the operation have much better reliability and more suitable when used.

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