

Development and Production of Modern Devices of Power Electronics at the Elektroypryamitel' JSC

VLADIMIR V. CHIBIRKIN, VYACHESLAV V. ELISEYEV, EUGENIE M. GEIFMAN and ANDREY N. EPISHKIN

*Elektroypryamitel' JSC,
Ul. Proletarskaya 126, Saransk 430001 (Russia)*

E-mail: ovbp@mail.ru

Abstract

Information is presented on the modern status and outlooks of the production of power electronic devices (PED) at the Elektroypryamitel' JSC. It is demonstrated that the development and introduction into large-scale manufacturing process of all the modern PED classes earlier manufactured in the USSR, as well as qualitatively new types of devices, i.e. high-power high-voltage semiconductor devices developed on the basis of broad introduction of the achievements of science and technology, allowed achieving the outstanding industrial results and solving the most important problem of the national economy aimed at the provision of all the branches of industry of the Russian Federation with modern classes of reliable and high-efficiency home-manufactured semiconductor devices, including those for energy- and resource-saving technologies, modern armament systems, electrified transport, municipal services, excluding the dependence on import, which makes an important constituent of the conservation of national safety and economic independence of Russia.

Power electronic devices (PED) are the main element basis of the power transforming means. Their characteristics define the efficiency of transforming devices that are used in all the branches of the Russian national economy, including electric power engineering (power transmission lines, hydro-, heat, electro-, and atomic power stations), electrified transport (railway, city, water, and air), ferrous and nonferrous metallurgy (the electrolysis of nonferrous metals, rolling mills, *etc.*), powerful technological and energetic equipment of all the plants, communal services (heat- and water supply for cities), defense branches, navy, aeronautics, rocket and space technologies, *etc.*

At present, about 10 million devices with the total capacity of ~100 million kW are in operation in Russia. Such a scale of transformations naturally requires high-efficiency PED which would be reliable and durable in operation. Because of high and constantly growing need in PED, 6 plants were engaged in their production over the territory of the USSR in early 90-ies: Elektroypryamitel' Industrial

Association, Saransk, Russia; M. I. Kalinin TEZ, Tallinn, Estonia; Preobrazovatel' Industrial Association, Zaporozhye, Ukraine; Kadzhi-Sai Association of Electrotechnical Plants, Kadzhi-Sai (Kirgizia); Modul' Plant, Stavropol', Russia; Molodechno Plant of Power Semiconductor Rectifiers (MPPSR), Molodechno, Byelarus. Each of these plants was specialized at the development and production of the devices of different classes.

The production established at these plants allowed at that time to produce the whole range of semiconductor devices manufactured all over the world and to meet the demands of the national economy in all the kinds of PED.

However, after the break-up of the USSR, the major part of plants producing power electronic devices turned out to be outside Russia. Because of this, to continue manufacturing transformers, it was necessary to import a substantial amount of PED devices. Besides, intense investigations carried out in the 80-ies and 90-ies in the industrially developed countries have led to the establishment of large-

scale production of new PED classes including high-voltage devices with increased fast-operation (HVDIFO), confinable thyristors (GTO), isolated-gate bipolar transistors (IGBT), super-power thyristors and diodes.

Unique characteristics of these devices had a decisive effect on practically all the aspects of the theory and practice of power transforming devices. Their use in industrially developed countries of Europe, America and Asia allowed to carry out fundamental technical re-equipment of energy consumption by passing to the use of the transformed electric energy at the frequency differing from the initial frequency of the manufactured energy. The consumption of the transformed electricity is the basis of energy- and resource-saving.

Another not less important problem that was solved by using the transformed electric energy is the saving of material resources in the form of expensive electrotechnical metals including copper, aluminium and steel, as well as expensive insulating materials for the manufacture of transforming devices.

In Russia, large-scale production of these devices was not established; technical re-equipment in the area of electric energy consumption was not carried out because the cost of energy, as well as the cost of electrotechnical copper, steel and non-mechanized labour were extremely low.

As a result, today when the prices of energy and material resources have grown up, Russia intolerably lags behind the developed countries in the consumption of transformed energy (15 %, compared to 60–70 %, respectively).

The national economy of the country involves large number of very low-efficient energy consumption objects of municipal services, heat and electric power engineering, rail-way transport, *etc.*

For example, historical situation provides that electric supply to many large-scale technical systems (self-needs of heat power stations, heat and water supply of cities, *etc.*) is based on non-controllable high-voltage asynchronous motors operating at a constant rotation speed calculated for maximum productivity, while the flows are controlled by throttling. As a result, the mean daily energy con-

sumption exceeds the necessary minimum substantially, sometimes by up to 60 %. Equipping the existing powerful electric motors with a frequency transformer on the basis of up-to-date high-power high-voltage semiconductor devices (HPHVSD) allows controlling the flows by varying the speed of motor rotation thus saving large amounts of electric energy.

Within the recent 5–6 years, the situation has changed dramatically in Russia because of the increase of the cost of electric energy and material resources; the problem of energy and resource saving in the most energy-consuming branches of national economy became extremely urgent. It is necessary to take account of the fact that a strong dependence on import in the production and consumption of PED in the branches of the national economy having a direct effect on the life of the major part of population and the country in general is very undesirable.

Because of this, the problem connected with the development of large-scale production of all the modern types of PED that were manufactured in the former USSR, as well as new classes of PED, became urgent. So, the *Elektrovpyramitel' JSC*, basing on the results of investigations in the area of physical processes in high-power semiconductor devices and on mastering of the technology of the manufacture of devices and initial silicon, has developed within a very short time the large-scale production of all the modern types of PED that were manufactured earlier in the USSR, including fast-operation and avalanche thyristors, fast-recovering diodes and voltage limiters manufactured by the *M. I. Kalinin TEZ*; thyristors and triacs of the small-size series including opto-thyristors manufactured by the *Preobrazovatel' Co.*; low-frequency, avalanche, fast-recovering diodes of the small-size series manufactured earlier in *Kadzhi-Sai*, small-size modules manufactured by the *Modul' Plant*, and practically all the new classes of PED. In particular, these include new series of high-voltage thyristors and diodes with increased fast-operation for current up to 1000 A with recurrent voltage up to 6000 V; a series of the confinable thyristors for current up to 2000 A with recurrent voltage up to 5000 V; a series of IGBT modules (80 types in manufacture)

for current up to 1200 A with recurrent voltage up to 3300 A.

By present, the *Elektrovypryamitel' JSC* is the only plant in Russia manufacturing practically all the modern types of power electronic semiconductor devices for current 10 to 6300 A, voltage up to 6000 V.

The power semiconductor devices under production possess high quality corresponding to the level achieved in the world, which is provided by perfect technological equipment, including that purchased according to the license from Siemens Company (Germany), and by modern technological processes, in particular such as precise control of the distribution of the concentrations of doping admixtures, radiation technological processes, including irradiation with electrons and protons, laser technologies, etc. The technology of the production of power electronic devices at the *Elektrovypryamitel' JSC* has been certified according to the ISO Standard 9001.

The developed devices in their technical characteristics completely correspond to the best foreign analogs manufactured by such leading companies as Eupec, ABB, Siemens, Toshiba, etc.; in some parameters these devices are even much better than the foreign analogs. The price of the home-made devices is lower than the price of the foreign devices by 30–50 %.

A large volume of marketing survey was carried out during the development of these devices; as a result, the devices have found wide application in the national economy, first of all in electrified transport and high-power engineering, municipal services of large cities. On this basis, new generations of high-efficiency transformers were developed that allow substantial (up to 50 %) decrease of the dimensions and increase of the reliability of electrotechnical equipment thus achieving up to 40–50 % of electric energy saved.

These transformers are successfully used in the Moscow district (Mytishchi, Shchelkovo, Tomilino, Noginsk), in Murmansk, Saransk, Pen-

za, Nizhny Novgorod, Samara, Barnaul, Ekaterinburg, Sochi, Orenburg, Belgorod, Uzhgorod and other cities of Russia and FSU states.

The development and mastering, at the *Elektrovypryamitel' JSC*, of the large-scale production of all the modern classes of PED that were manufactured earlier in the USSR, as well as qualitatively new hardware, namely, high-power high-voltage semiconductor devices developed on the basis of broad introduction of scientific and technological achievements allowed us to achieve outstanding results and to solve the most important economic problem connected with the provision of all the branches of the Russian National Economy with modern classes of reliable high-efficiency home-made semiconductor devices including those for energy- and resource-saving technologies, modern weapon systems, electrified transport, and exclude the dependence on import, which makes an important part for the sake of conserving the national safety and economical independence of Russia.

The technical level of Si achieved by present generally provides the required quality of the manufactured semiconductor devices. Nevertheless, a uniform and goal-directed technical policy is necessary in the manufacture of silicon.

The production of the devices of new generations requires silicon with large diameter (up to 150 mm) with small scattering of specific resistance, with long lifetimes of non-equilibrium charge carriers ($\sim 100\text{--}600\ \mu\text{s}$) and small (<10 %) scattering in area, the density of structural defects being not more than $100\ \text{cm}^{-2}$.

The next substantial step to the development of power electronics that may occur within the nearest 5 years will be the development of the production of PED based on silicon carbide (SiC). The *Elektrovypryamitel' JSC* together with the A. F. Ioffe Physicotechnical Institute (RAS), and the St.-Petersburg State Electrotechnical University (SPSEU) plan to start the development of these devices.