ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 10, Issue 11, November 2023

Evolution of Semiconductor Devices and Valve Converters Based on Them

S.B.Umarov

DSc, Professor, Tashkent State Technical University, Republic of Uzbekistan, Tashkent

ABSTRACT: The article presents the results of the analysis of the stages of development of high-current semiconductor devices production technology, studies the expansion of power ranges and frequencies of their use, and presents information about modern power circuit topologies of valve converters produced by the world's leading firms. Technical characteristics of autonomous current inverters made on the basis of using high-current semiconductor devices are given.

KEY WORDS: high-current semiconductor devices, production technology, gate frequency converter, autonomous current inverter.

I. INTRODUCTION

The development of converter units based on fully controlled thyristors has led to a significant increase in the development and implementation of high-current electronic devices. According to the forecast of the German statistical firm Statista Gm BH, in the period from 2018 to 2029, the market for sales of automotive inverters based on metal oxide semiconductor field-effect transistors (MOSFETs) is expected to grow significantly. So, if sales in 2018 amounted to 121.6 million US dollars, then in 2029 this figure will increase approximately 68 times and amount to 8.3 billion US dollars.

Such intensive development of the element base of power electronics helps to increase the specific power of the implemented converters and significantly increases the range of operational, technical and economic characteristics. Below in Fig. 1 is a diagram of the stages of development of controlled thyristors and high-voltage transistors [1- 3].

II. THE DEVELOPMENT OF THYRISTORS AND HIGH-VOLTAGE TRANSISTORS

The development of technologies for the production of high-current devices, the expansion of power ranges and frequencies of their use, as well as their high demand on the world market, have led to the development of circuit topologies for autonomous current inverters (ACI) and valve converters in general.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 10, Issue 11, November 2023

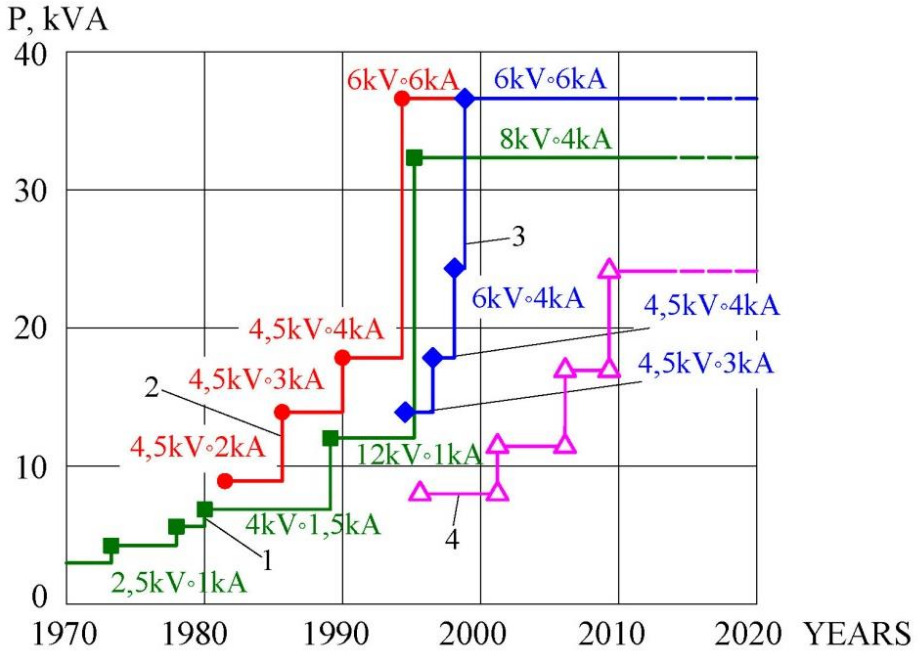

Fig 1. Diagram of the stages of development of thyristors and high-voltage transistors: 1 - traditional uncontrolled thyristors; 2 - lockable thyristors such as GTO, IGCT; 3 - lockable thyristors type GCT; 4 - high-voltage transistors such as IGBT, MOSFET.

III. THE DEVELOPMENT OF SEMICONDUCTOR CONVERTERS

The prospects for "new" topologies lie in the development of autonomous inverter (AI) circuits based on the synthesis of the harmonic composition of the output voltages and currents of the inverters [2, 4]. Below in Fig. 2 shows a diagram showing the scope of use of modern types of semiconductor devices in the range of powers and switching frequencies.

The development of new topologies of semiconductor converters in the direction of high-current energy electronics involves the development of multi-level and matrix circuits of autonomous current inverters.

Multilevel converters, in order to improve the harmonic composition, provide for an increase in the number of steps in the output voltage forms of inverters, and matrix converters - single-level autonomous current inverters, perform the same functions of improving the quality of the output voltage form using pulse width modulation (PWM) and pulse width control (WID), pulse frequency modulation (PFM), etc. [4, 5].

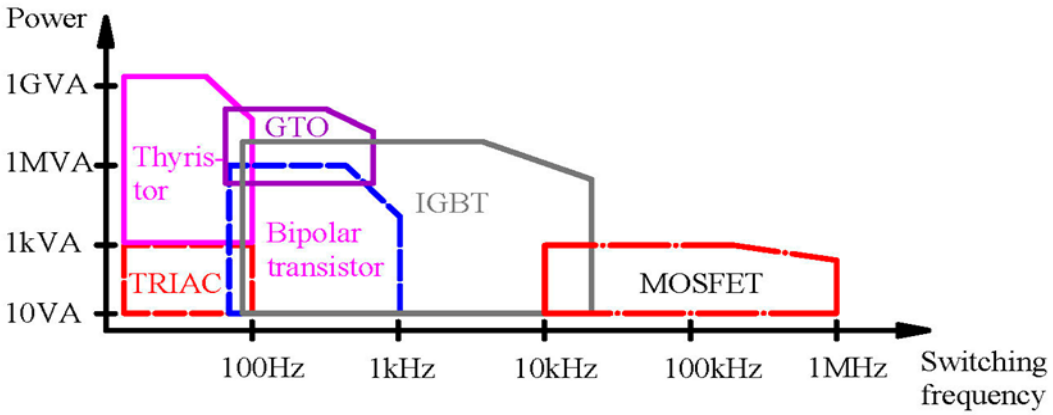

Fig. 2. Diagram showing the scope of use of modern types of semiconductor devices in the range of powers and switching frequencies

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 10, Issue 11, November 2023

The basic topology of a three-level single-phase ACI based on controlled thyristors is shown in Fig. 3 [6].

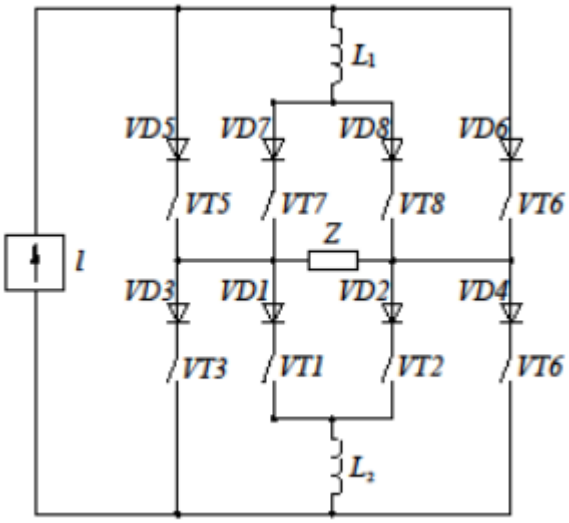

Fig. 3. Basic topology of three-level single-phase CAI

The direction of development of circuit solutions for matrix converters involves the installation of capacitor filters on the side of the supply voltage or load, as well as in both directions simultaneously. Such conditions arise due to the need to organize stable switching of valves during PWM or other types of modulation. A typical circuit of such converters ACI with cut-off gates (ACI with COG) is shown in Fig. 4.

The American company Power Flex 7000 Allen Bradley produces frequency converters built on the basis of ACI with PWM [7]. The converter uses SGCT thyristors, which provides a higher modulation frequency: 440-1000 Hz, compared to 200-225 Hz. for GTO thyristors, which makes it possible to obtain a higher sinusoidal coefficient of the inverted current and voltage waveforms.

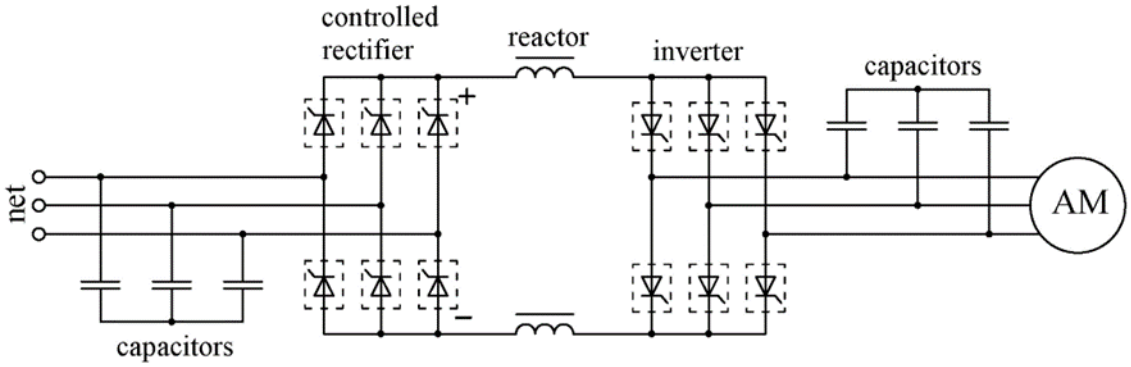

Fig. 4. Typical frequency converter circuit built based on ACI with PWM

In accordance with [8-10], valve converters based on autonomous current inverters are mainly used to implement the following practical purposes:

- power supply to the AC consumer in devices with an energy source in the form of a battery;
- power supply for guaranteed power supply units and uninterruptible power supply units;
- provision of adjustable voltage and frequency for electric drives with asynchronous and synchronous motors;

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 10, Issue 11, November 2023

- electric vehicles powered from a contact network or a direct current source, using asynchronous motors with a squirrel-cage rotor as traction motors;

- power supply with alternating current of high frequency to electrical technological installations for various purposes (electrothermy, metal smelting, heating, hardening, etc.).

- stabilized AC power supplies (computer technology, radio and wire communications, control and automation equipment, electric transport).

In addition to the traditional range of use of valve converters based on autonomous current inverters described above, the possibility of their use in wind power and solar power for the development of renewable power sources has recently been of great practical interest [11,12].

Table 1 below presents the Technical characteristics and scope of valve converters built on the basis of various power circuits of autonomous current inverters (ACI) produced by the world's leading companies.

Table 1

Technical characteristics of valve converters based on ACI

№	Company manufacturer	ACI scheme	Technical data
1	Seriya PCHIT Tehnoross, Rossiya	ACI with COG	P = 160-2000 kVt U = 380B, 660B, 1140 V
2	Seriya PCHVM Electroteks, Rossiya	Bridge ACI	P = 250-5600 kVt U =3, 6, 10 kV
3	PCH -01 MIR, Rossiya	Bridge ACI	P = 630-5000 kVt U = 6, 10 kV
4	AT09 TRIOL, Rossiya	Bridge ACI	P = 630-5000 kVt U = 6, 10 kV
5	NPM «EKRA», Rossiya	Bridge ACI	P = 630-5000 kVt U = 6, 10 kV
6	PCHTE NPP «EOS», Ukraina	Bridge ACI	P = 1600-8000 kVt U =6, 10 kV
7	PCHT-1M NII «HEMZ», Ukraina	Bridge ACI	P = 50-1600 kVt U =380, 660 V
8	Power Flex 7000 Rockwell, USA	ACI with COG	P = 630-12500 kVt U =3,3-13,5 kV
9	Ross Hill, USA	ACI with COG	P = 630-12500 kVt U =3,3-13,5 kV
10	Hill Gracham, USA	ACI with COG	P = 630-12500 kVt U =3,3-13,5 kV
11	Imvar, England	ACI with COG	P = 630-12500 kVt U =3,3-13,5 kV
12	Silcovert Ansaldo, Italy	ACI with COG	P = 630-12500 kVt U =3,3-13,5 kV
13	Серия 1557 M Allen Bradle, Canada	ACI with PWM	P = 630-12500 kVt U =3,3-13,5 kV
14	Power Flex 7000 Allen Bradle, Canada	ACI with PWM	P = 630-12500 kVt U =3,3-13,5 kV
15	Hyunday, South Korea	ACI with PWM	P = 630-12500 kVt U =3,3-13,5 kV
16	ALSPA CDL8000, France	Bridge ACI	P = 5MVA-13,5 MVA U =3,3-13,5 kV

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 10, Issue 11, November 2023

In addition to the above circuit solutions, currently one of the most promising areas in the development of power electronics is the development and use of intelligent power modules. This occurs due to the constant improvement of manufacturing technology and improvement of the technical characteristics of high-power field-effect transistors - MOSFET and IGBT, power drivers with a high degree of integration [13, 14]. The most successful companies working in this direction are Mitsubishi, Fairchild, International Rectifier, Siemens, Schorch, BM Elektronic, Transrech Antriebs systeme Berlin, Relience Elektric, Germany; Hill Graham Control, USA; "Asi Robicon", Italy - USA; Alstom, France; Allen Bradley, USA-Canada; ESTEL PLUS, Estonia; NPP "EOS", Ukraine, etc. [13-15].

IV. CONCLUSION

The stages and prospects for the development of valve converters in general and autonomous current inverters (ACI) in particular, outlined in the review, allow us to judge the current state of the design, manufacture and implementation of highly efficient DC-AC converters. Based on the analysis, it was established that at present thyristor autonomous inverters have not lost their importance in power transmission systems and in industrial installations.

Fundamental scientific principles achieved over the past few decades, covering a large volume of modeling methods, software products, as well as practical skills in the development and implementation of thyristor converters, are an integral basis for the development of modern converters based on hybrid and smart IGBT and IGCT modules.

REFERENCES

1. Ichiro Omura. Power semiconductor device: Basics Kyushu Institute of Technology, Japan. Since 1909 IEEE EDS Webinar Dec. 2, 2015
2. Pronin M.V., Vorontsov A.G. Power Fully Controlled Semiconductor Converters (Modeling and Calculation). St. Petersburg: Elektrosila Publ., 2003, 171 p.
3. Rozanov Y.K. Main stages of development and current state of power electronics.- Electricity, 2005, No7. pp. 52-62
4. Donskoy N., Ivanov A., Matison V., Ushakov I. Mnogolevelovye avtonomnye invertors dlya melektroprivoda i elektroenergetiki [Multilevel autonomous inverters for electric drive and electric power engineering]. - 2008, №1. - P.43-46.
5. Sidorov, S. (2009) "Matrix Frequency Converter – Object of Scalar Control," Power Electronics, No. 3, 2009. - pp. 31-36
6. Malnev A.I., Bakhovtsev I.A., Zinoviev G.S. Review of multilevel inverters of wind power stations. Engineering of georesources. 2015. T.326. No7.- P. 15-26
7. Egorov A.N., Semenov A.S., Fedorov O.V. Practical experience of applying frequency converters POWER FLEX 7000 in the mining industry//Publishing house of NSTU.- 2017, No.4, pp.86-93.
8. Zabrodin Y.S. Promyshlennaya elektronika: uchebnik dlya vuzov [Industrial electronics: textbook for universities]. Moscow, Alliance Publ., 2013. - 496 p. (in Russian).
9. Zinoviev G.S. Power Electronics. Moscow, Yurayt Publ., 2015, 667 p.
10. Tomashevsky D.N. Autonomous Invertors. A manual allowance. - Yekaterinburg: Izd-vo Ural. On, 2019. - 120 p.
11. Umarov Sh. B. Results of the Development of an Energy-effective Automatised Solar Battery Cooling System With Frequency Control // International Journal of Advanced Research in Science, Engineering and Technology. India, 2022.- Volume 9, Issue 7, Iuly 2022. ISSN: 2350-0328. PP. 19483-19486 (05.00.00; № 8).
12. Mahendra Lalwani, D. P. Kothari, Mool Singh, Investigation of Standalone Current Source Inverter for Photovoltaic System. International Journal of Physical and Mathematical Sciences Vol 3, No 1 (2012), pp. 91-97
13. Bashkirov V. Intelligent power modules of the International Rectifier company for low-power drives. 2005. No2.-S. 30-35.
14. Alam, K.S., Xiao, D., Zhang, D., et al.: 'Single-phase multicell AC-DC converter with optimized controller and passive filter parameters', IEEE Trans. Ind. Electron., 2019, 66, (1), pp. 297–306.
15. Feng, L., Korvink, J.G., Benner, P.: 'A fully adaptive scheme for model order reduction based on moment-matching', IEEE Trans. Compon. Packag. Manuf. Technol., 2015, 5, (12), pp. 1872–1884