

MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION
Federal State Autonomous Educational Institution for Higher Education
«North-Caucasus Federal University»

APPROVED BY

Dean of FPE of NCFU
Candidate of Technical Sciences,
Associate Professor A.E. Verisokin

COURSE SYLLABUS
«Modern Power Electronics»

Field of study	<u>13.04.02 Electric Power Engineering and Electrical Engineering</u>
Specialization (Profile)	<u>Intelligent Power Supply Systems</u>
Year of commencement of studies	<u>2026</u>
Mode of study	<u>full-time</u>
Implemented in semester(s)	<u>2</u>

DEVELOPED BY:

Candidate of Technical Sciences,
Associate Professor of the Department of
Automated Electric Power Systems and
Power Supply, D.A. Kostyukov

1. Purpose and objectives of studying the discipline (module)

The goal of mastering the discipline is to develop students' ability to apply fundamental and advanced knowledge of modern power electronics to the analysis, design, modeling, control, and operation of power electronic converters and semiconductor devices used in electric power engineering and electrical engineering systems, including renewable energy sources, energy storage systems, electric drives, electric vehicle charging infrastructure, FACTS/HVDC equipment, and intelligent power supply systems.

The objectives of the discipline are to study the operating principles and characteristics of modern power semiconductor devices and gate-drive systems; to master the selection, modeling, and calculation of AC-DC, DC-DC, DC-AC, multilevel, and bidirectional converter topologies; to develop skills in applying PWM modulation, feedback control, digital control, protection, thermal management, and EMI/EMC mitigation methods; to form the ability to evaluate the integration of converter-based equipment into power systems in accordance with technical, reliability, efficiency, and electromagnetic compatibility requirements; and to prepare students for solving engineering tasks related to renewable energy converters, electric drives, EV chargers, energy storage interfaces, FACTS, HVDC, and other modern power electronic systems.

2. Place of the discipline (module) in the structure of the educational program

The discipline "Modern Power Electronics" belongs to the part formed by the participants of educational relations within the educational program. It is studied in the 1th semester.

3. List of planned learning outcomes for the discipline (module), mapped to the planned outcomes of the educational program

Competency code and formulation	Indicator code and formulation	Planned learning outcomes for the discipline (module) describing the stages of competency and indicator formation
PC-3 Capable of managing the power system operating mode of an electrical power supply system using digital technologies	ID-4 PC-3 Applies knowledge of the specific features of installation, start-up and commissioning, adjustment, testing, and acceptance into service of various types of electrical power and electrotechnical equipment.	Capable of managing the power system operating mode of an electrical power supply system

4. Scope (credit load) of the academic discipline (module) and forms of control

Total study load: 4 credits / 144 academic hours	In academic hours
Contact work:	54
Lectures / of which practical training	0 / 0
Laboratory works / of which practical training	0 / 0
Practical classes / of which practical training	54 / 0
Independent work	90
Forms of control:	
Exam	—
Pass/Fail (Credit)	2th semester
Graded Pass/Fail (Credit with grade)	—
Course project/paper	—

* The discipline (module) provides for the use of e-learning and distance educational technologies (unless otherwise stipulated by the educational standard).

5. Content of the discipline (module), structured by topics (sections), indicating the number of hours and types of classes

№	Section (topic) of the discipline and brief content	Formed competencies and indicators	Full-time form				Forms of ongoing progress control
			Contact work of students with the teacher / of which in the form of practical training, hours			Independent work, hours	
			Lectures	Practical classes	Laboratory works		
1	Topic 1. Modern power electronics fundamentals. Converter functions in power supply systems. Classification of AC-DC, DC-DC, DC-AC, and AC-AC conversion; applications in renewable generation, electric drives, energy storage, microgrids, and smart grids.	ID-4 PC-3		4		6	Interview
2	Topic 2. Power semiconductor devices and gate-drive systems. Operating principles and application areas of power diodes, thyristors, IGBT, MOSFET, SiC, and GaN devices. Static and dynamic characteristics, switching losses, safe operating area, isolation, gate-drive requirements, and protection circuits for high-power converter systems.	ID-4 PC-3		4		6	Interview

3	Topic 3. AC-DC conversion: diode and controlled rectifiers. Single-phase and three-phase uncontrolled and controlled rectifier circuits. Analysis of average output voltage, commutation effects, input current distortion, power factor, and selection of rectifier topologies for industrial power supplies and DC links.	ID-4 PC-3		4		6	Interview
4	Topic 4. Active front ends and power factor correction converters. Principles of boost PFC stages and PWM active rectifiers. Sinusoidal current shaping, DC-link voltage regulation, bidirectional power flow, regenerative operation, and compliance with harmonic emission requirements in modern converter installations.	ID-4 PC-3		4		6	Interview
5	Topic 5. DC-DC converter topologies and magnetic components. Buck, boost, buck-boost, Cuk, SEPIC, flyback, forward, half-bridge, and full-bridge converters. Continuous and discontinuous conduction modes, duty-cycle relationships, ripple estimation, transformer and inductor design, and practical efficiency considerations.	ID-4 PC-3		4		4	Interview

6	Topic 6. Voltage-source inverters and PWM modulation methods. Single-phase and three-phase voltage-source inverter structures. Sinusoidal PWM, space-vector PWM, overmodulation, dead-time effects, switching frequency selection, output voltage control, and harmonic spectra of inverter-fed loads and grid interfaces.	ID-4 PC-3		4		6	Interview
7	Topic 7. Multilevel and modular power converter structures. Neutral-point-clamped, flying-capacitor, cascaded H-bridge, and modular multilevel converter topologies. Voltage balancing, modulation principles, scalability, semiconductor stress, and applications in medium-voltage drives, STATCOMs, and HVDC systems.	ID-4 PC-3		4		6	Interview
8	Topic 8. Converter modeling, feedback control, and digital implementation. State-space averaging, small-signal models, transfer functions, and closed-loop control of power converters. Current-mode and voltage-mode control, PI regulators, sampling effects, digital PWM generation, stability margins, and practical controller tuning.	ID-4 PC-3		4		6	Interview

9	Topic 9. Thermal management, protection, and reliability of converters. Thermal resistance networks, junction temperature estimation, heatsink selection, cooling methods, overload capability, short-circuit and overvoltage protection, snubber circuits, derating, reliability prediction, and failure mechanisms in power electronic equipment.	ID-4 PC-3		4		6	Interview
10	Topic 10. EMI/EMC and power quality in converter-fed systems. Conducted and radiated electromagnetic interference generated by switching converters. Common-mode and differential-mode noise, grounding, shielding, filter design, harmonic distortion, flicker, and mitigation measures for reliable operation in power supply networks.	ID-4 PC-3		4		6	Interview
11	Topic 11. Grid-connected converters for renewable energy sources. Power electronic interfaces for photovoltaic arrays, wind turbines, and distributed generation units. Maximum power point tracking, grid synchronization by PLL, current control, reactive power support, low-voltage ride-through, and grid-code-oriented converter functions.	ID-4 PC-3		4		4	Interview
12	Topic 12. Energy storage interfaces and bidirectional conversion. Bidirectional DC-DC converters, battery energy storage system architectures, supercapacitor interfaces, DC microgrids, charge-discharge control, state-of-charge constraints, galvanic isolation, and power management strategies for hybrid energy systems.	ID-4 PC-3		2		6	Interview

13	Topic 13. FACTS and HVDC converter technologies. Power electronic equipment for transmission and distribution networks: SVC, STATCOM, TCSC, UPFC, and HVDC converters. Reactive power compensation, voltage control, power-flow regulation, converter station structure, and system-level operating requirements.	ID-4 PC-3		2		4	Interview
14	Topic 14. Electric drives and traction power electronics. Converter-fed AC and DC electric drive systems. Inverter control of induction and permanent-magnet motors, regenerative braking, traction converter architectures, onboard auxiliary converters, and coordination between drive performance, efficiency, and grid impact.	ID-4 PC-3		2		6	Interview
15	Topic 15. EV charging infrastructure and onboard power conversion. AC and DC charging systems for electric vehicles, onboard chargers, isolated DC-DC stages, fast-charging station architectures, communication and control functions, bidirectional vehicle-to-grid concepts, and converter-related requirements for distribution networks.	ID-4 PC-3		2		6	Interview

16	Topic 16. Design case studies and system-level integration. Practical analysis of modern power electronic systems for industrial facilities, renewable energy plants, microgrids, electric transport, and intelligent power supply systems. Selection of converter topology, semiconductor devices, control strategy, cooling, protection, and compliance measures for a complete engineering solution.	ID-4 PC-3		2		6	Interview
	TOTAL			54		90	

6. Assessment tools for ongoing progress control and intermediate assessment of students in the discipline (module)

The goal of mastering the discipline is to develop students' ability to apply fundamental and advanced knowledge of modern power electronics to the analysis, design, modeling, control, and operation of power electronic converters and semiconductor devices used in electric power engineering and electrical engineering systems, including renewable energy sources, energy storage systems, electric drives, electric vehicle charging infrastructure, FACTS/HVDC equipment, and intelligent power supply systems.

The objectives of the discipline are to study the operating principles and characteristics of modern power semiconductor devices and gate-drive systems; to master the selection, modeling, and calculation of AC-DC, DC-DC, DC-AC, multilevel, and bidirectional converter topologies; to develop skills in applying PWM modulation, feedback control, digital control, protection, thermal management, and EMI/EMC mitigation methods; to form the ability to evaluate the integration of converter-based equipment into power systems in accordance with technical, reliability, efficiency, and electromagnetic compatibility requirements; and to prepare students for solving engineering tasks related to renewable energy converters, electric drives, EV chargers, energy storage interfaces, FACTS, HVDC, and other modern power electronic systems.

7. Methodological guidelines for students on mastering the discipline

When starting work, each student should take into account the following provisions.

The discipline (module) is organized thematically; each topic represents a logically complete section.

Practical classes are conducted to consolidate the acquired information and develop skills in applying it to solve practical problems in the relevant subject area.

Students' independent work is aimed at independently studying additional material, preparing for practical and laboratory classes, as well as completing all types of independent work.

For successful mastery of the discipline, it is necessary to complete all types of independent work using the recommended information sources.

8. Educational, methodological, and informational support of the discipline

8.1. List of basic and additional literature required for mastering the discipline (module)

8.1.1. List of basic literature:

1. Rozanov Yu.K., Ryabchitskiy M.V., Kvasnyuk A.A. Power Electronics: Textbook for Universities. 2nd ed. – Moscow: MEI Publishing House, 2009.
2. Mohan N., Undeland T.M., Robbins W.P. Power Electronics: Converters, Applications, and Design. 3rd ed. – Hoboken: John Wiley & Sons, 2003.
3. Erickson R.W., Maksimovic D. Fundamentals of Power Electronics. 2nd ed. – New York: Springer, 2001.
4. Zinoviev G.S. Fundamentals of Power Electronics: Textbook. – Novosibirsk: NSTU Publishing House, 2003.
5. Abu-Rub H., Malinowski M., Al-Haddad K. Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications. – Chichester: John Wiley & Sons, 2014.

8.1.2. List of additional literature:

1. German-Galkin S.G. Computer Modeling of Semiconductor Systems in MATLAB 6.0: Textbook. – Saint Petersburg: KORONA Print, 2007.
2. Semenov B.Yu. Power Electronics: Professional Solutions. – Moscow: SOLON-Press, 2011.
3. Teodorescu R., Liserre M., Rodriguez P. Grid Converters for Photovoltaic and Wind Power Systems. – Chichester: John Wiley & Sons, 2011.
4. IEEE Std 1547-2018. IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces. – New York: IEEE, 2018.

5. IEC 61800-3:2017. Adjustable speed electrical power drive systems – Part 3: EMC requirements and specific test methods. – Geneva: International Electrotechnical Commission, 2017.

6. IEC 61000-3-2:2018. Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions. – Geneva: IEC, 2018.

8.2. List of educational and methodological support for students' independent work in the discipline (module)

1. Methodological Guidelines for Practical Classes in the Discipline «Modern Power Electronics» for Students in the Field of Study 13.04.02 Electric Power Engineering and Electrical Engineering / Compiled by D.A. Kostyukov. – Stavropol: North-Caucasus Federal University, 2026.

2. Methodological Recommendations for Organizing Independent Work of Students in the Disciplines of the Field of Study 13.04.02 Electric Power Engineering and Electrical Engineering (Master's programme) / North-Caucasus Federal University. – Stavropol: NCFU, 2026.

8.3. List of resources of the information and telecommunications network "Internet" necessary for mastering the discipline (module)

1. <http://biblioclub.ru> Electronic Library System «University Library Online»
2. <http://catalog.ncstu.ru> Electronic Catalog of the Association of Electronic Libraries of Educational Institutions and Organizations of the North Caucasus Federal District
3. <http://www.iprbookshop.ru> Electronic Library System IPR SMART
4. <http://window.edu.ru/> Unified Window of Access to Educational Resources
5. <http://openedu.ru> National Online Learning Portal «Open Education»
6. <https://www.iec.ch> Official website of the International Electrotechnical Commission (IEC) – access to IEC standards and technical resources
7. <https://ieeexplore.ieee.org> IEEE Xplore Digital Library – access to IEEE standards, journals and conference papers on power electronics, converter systems, electric drives, renewable energy converters and smart grids.
8. <https://minenergo.gov.ru/> Official website of the Ministry of Energy of the Russian Federation

9. List of information technologies used in the educational process for the discipline (module), including the list of software and information reference systems

During lectures, computer equipment and presentation of multimedia materials are used. In seminar and practical classes, students present presentations prepared by them during independent study hours.

Information reference systems:

Information reference and information legal systems used in the study of the discipline:

1	ConsultantPlus – http://www.consultant.ru/
2	https://minenergo.gov.ru/ – Official website of the Ministry of Energy of Russia

Software:

1	Alt Workstation 10
2	Alt Workstation K
3	Alt Server
4	Office suite – R7-Office

10. Description of the material and technical base necessary for the implementation of the educational process in the discipline (module)

Practical classes	Classroom for conducting training sessions, equipped with multimedia equipment and technical teaching aids.
Independent work	A room for independent work of students, equipped with computer equipment with the ability to connect to the Internet and access to the university's electronic information and educational environment.

11. Features of mastering the discipline (module) by persons with disabilities

Students with disabilities are provided with special textbooks, teaching aids and didactic materials, special technical means of learning for collective and individual use, services of an assistant who provides students with the necessary technical assistance, as well as sign language interpreting and typhlo-sign language interpreting services.

Mastering the discipline (module) by students with disabilities may be organized together with other students, as well as in separate groups.

Mastering of the discipline (module) by students with disabilities is carried out taking into account the characteristics of psychophysical development, individual capabilities and health status.

In order to ensure accessibility of higher education under the educational program for persons with disabilities when mastering the discipline (module), the following is provided:

1) For persons with visual disabilities:

- presence of an assistant who provides the student with the necessary technical assistance taking into account individual characteristics (helps to take a seat, move around, read and complete the task, including writing under dictation);
- written assignments, as well as instructions on the procedure for their completion, are formatted in enlarged font;
- special textbooks, teaching aids and didactic materials (with large print or audio files);
- individual uniform lighting of at least 300 lux;
- if necessary, a magnifying device is provided to the student for completing the task.

2) For persons with hearing disabilities:

- presence of an assistant who provides the student with the necessary technical assistance taking into account individual characteristics (helps to take a seat, move around, read and complete the task, including writing under dictation);
- provision of collective sound amplification equipment; if necessary, the student is provided with individual sound amplification equipment;
- provision of appropriate sound means of information reproduction.

3) For persons with musculoskeletal disorders (including those with severe motor impairments of the upper limbs or absence of upper limbs):

- written assignments are performed on a computer with specialized software or dictated to an assistant;
- at the student's request, assignments may be completed orally.

12. Features of implementing the discipline using distance educational technologies and e-learning

According to Part 1 of Article 16 of Federal Law No. 273-FZ of December 29, 2012 "On Education in the Russian Federation," e-learning is understood as the organization of educational activities using information contained in databases and used in the implementation of educational programs, information technologies and technical means that ensure its processing, as well as information and telecommunications networks that ensure the transmission of said information through communication lines and the interaction of students and teaching staff. Distance educational technologies are understood as educational technologies implemented primarily using

information and telecommunications networks with indirect (remote) interaction between students and teaching staff.

The discipline may be implemented using distance educational technologies and e-learning in whole or in part. The components of the educational and methodological set of the discipline (syllabus, assessment and methodological materials, forms of certification) implemented using distance educational technologies and e-learning contain an indication of their use.

When organizing educational activities using distance educational technologies and e-learning, asynchronous and synchronous methods of interaction between participants in educational relations via the information and telecommunications network "Internet" may be provided.

When using distance educational technologies and e-learning, the schedule for the discipline indicates: methods of interaction between participants in educational relations via the information and telecommunications network "Internet" (VCS – video conferencing, ET – electronic testing); links to the electronic information and educational environment of NCFU, to educational platforms and resources of other organizations to which open access is provided via the information and telecommunications network "Internet"; for synchronous learning – the time of online classes and the instructors; for asynchronous learning – the authors of online courses.

When organizing intermediate assessment using distance educational technologies and e-learning, the Methodological Recommendations on the use of technical means ensuring the objectivity of results during intermediate and state final assessment in higher education programs – bachelor's programs, specialist's programs and master's programs using distance educational technologies (Letter of the Ministry of Science and Higher Education of the Russian Federation dated December 7, 2020 No. MN-19/1573-AN "On sending methodological recommendations") are applied.

The implementation of the discipline using e-learning and distance educational technologies is carried out using the electronic information and educational environment of NCFU, to which students have access via the information and telecommunications network "Internet", or using resources of other organizations, including platforms that provide services for video conferencing, online meetings and distance learning (MTS-Link), as well as using the capabilities of social networks to facilitate communication between students and instructors.

The educational and methodological support of the discipline implemented using e-learning and distance educational technologies includes the syllabus, educational and methodological manuals or a lecture course, methodological guidelines for performing various types of learning activities provided for by the discipline, and other educational and methodological materials posted in the electronic information and educational environment of NCFU, all presented in electronic form.