

SHORT COMMUNICATIONS

The Innovative Research of Ukrainian Scientists in the Field of Analysis, Optimization and Automation of Energy Systems Modes in the Second Half of the 20th Century

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Abstract: The article is based on a study on analysis development, optimization and automation of complex power systems modes in Ukraine in the second half of the twentieth century. The study demonstrates for the first time the deployment of innovative scientific researches according to the development of methods and software simulation for power systems, relying on archival materials contributed by Ukrainian scientists. The article also introduces the scientific school of the Institute of Electrodynamics at NAS, Ukraine involved in the field of automation of power systems modes. The scientific school, founded by academician S. A. Lebedev, has developed in the works of L. V. Tsukernik, I. M. Sirota, B. S. Stogniy, A. V. Kirilenko, V. N. Avramenko, and others. The main research areas at the Institute of Electrodynamics are calculation of transient state and the stability of power systems; calculation and analysis of normal and emergency modes; calculation of settings of protection devices; analysis and forecasting of electrical loads; and development of operational mode control issues. Also, the activities of the higher electrotechnical school are taken into consideration. In Kyiv Polytechnic Institute, under the supervision of Professor V. G. Kholmisky, the most important research on the development of calculation theory, methodology of analysis and optimization of electrical networks modes were made. Professor G. I. Denisenko at the Lviv Polytechnic Institute initiated the ground-breaking development of the simultaneous electric power transmission of AC and DC.

Keywords: *Academy of Sciences of Ukraine, electrotechnics, Higher Technical School, Institute of Electrodynamics, scientific achievement*

The second half of the 20th century was a period of rapid development in science and technology, and especially in the field of applied engineering sciences. Gradually, researches were conducted not only by individual scientists but by powerful research teams. It was the beginning of a new stage related to the development of innovative course of research as new forms of organization of science emerged in Ukraine in the post-war period. The methods of management of Ukrainian science, such as planning of scientific research, coordination of taking measures, played an important role in the development of science. Almost all of the outstanding achievements of that period in science and technology took place only in the areas of military-industrial or related industries. Other areas of scientific knowledge were under severe ideological pressure and many scientists suffered from repressions. However, closer knowledge of scientific and technological achievements in the 20th century also sheds light on the achievements of Ukrainian scientists in many fields of science. The results of innovative researches of Ukrainian scientists in the conditions of Soviet artificial isolation were not known to a wider circle of the world's scientific community.

In the second half of the 20th century, powerful electrotechnical scientific research centers were formed at the Academy of Sciences of Ukraine and on the basis of higher technical educational institutions, where scientific and technological potential was concentrated, they were expected to implement high-tech development of national economic and defense significance. Researches on the development of modeling methods and tools for complex electrical power systems took the leading position in the works of Ukrainian scientists.

Developments in the implementation of devices and systems that managed the modes of electric power systems under normal and emergency conditions were carried out by many scientific organizations of different countries. When studying European and American experience, as well as the research of scientists from the republics of the USSR, it is possible to highlight the achievements of representatives of scientific schools of different countries. The investigations of the stability of power systems and power modeling were carried out by American scientists R. T. Byerly, E. W. Kimbark and S. B. Crary. The scientific works of Kimbark were of great importance for the stability of the operation of power systems. The scientific development of scientists such as J. Arroyo, N. verch, and J. Conejo contributed to the development of theoretical and practical

problems of automation of energy systems. The developments in ensuring the reliability of electric power systems were approached by J. Endrenyi. Based on the results of his research, the scientist systematized a number of mathematical models to determine the numerical values of reliability indicators of electric power systems and suggested methods for using reserves of generating capacity. Endrenyi developed the fundamentals of the reliability estimation theory of power systems, as well as practical applications of reliability theory to solve the problems of operation and planning of power system modes, such as determining the operational reserves of power plants and power systems, reliability of electric power supply for consumers from a particular distribution network, and parallel operation of powerful power system corporations. The calculation problems, regulation and protection of power systems and technical issues of electricity supply were successfully tackled by the French scientist R. Pelisie. In his fundamental scientific work, Pelisie generalized on the experience of designing and operating of European power systems, collected in the second half of the 20th century.

The important scientific research on the modeling of powerful energetic systems, the stability of electric power systems, the methods of their automatic regulation and management were carried out at the Moscow Power Engineering Institute under the lead of V. A. Venikov. At the G. M. Krzhizhanovsky Energy Institute, I. M. Markovich considered the problems of operation of power systems reliability, the quality of electricity and the stability of power system modes.

Scientists of the Siberian Branch of Russian Academy of Sciences, such as L. A. Krumm and A. Z. Gamm, carried out the tasks of automation of power systems and automated dispatching control. At the Tomsk Polytechnic University, the relay protection of electric power systems was studied by M. Ya. Kletsel.

The scientific school of the optimizing modes in the field of electric power systems was established at the Tashkent Polytechnic Institute in Uzbekistan under the guidance of Academician Kh. F. Fazylov. Studies on the modes of complex power systems based on the nodal method were carried out. Problems of mode optimization were also investigated at the Tallinn Polytechnic Institute in Estonia.

The theory and practice of power system operation modes were considered by V. G. Kholmsky at the Kyiv Polytechnic Institute, V. M. Khrushchev at the Kharkiv Polytechnic Institute, S. A. Lebedev and L. V. Tsukernik at the Institute of Electrodynamics of the Academy of Sciences of Ukraine, and others. The

historiography of this research problem consists of surveys of the development history of the institutions, where issues of the development of Ukrainian studies of power systems modes were partially covered. However, the work that would be directly dedicated to the establishment and development of studies of normal and emergency modes of power systems in Ukraine is still lacking.

The aim of the article is to evaluate the contribution of Ukrainian scientists to the development of research in the field of the analysis of modes of power systems in the second half of the 20th century based on the study of archival materials. In Ukraine, the beginning of the theoretical and experimental investigations of reliability and stability of electricity supply, and electric networks of high voltage could be dated to the first half of the 20th century. At the Kharkiv Technological Institute, Academician V. M. Khrushchev was involved in the development of calculation methodologies of high voltage power transmission lines, conducted research and development works on automatic control at power supply stations since 1923 (Tverytnykova, 2010, p. 212).

Further development of theoretical researches was connected with the founder of scientific schools in nonlinear mechanics, Academician N. M. Bogolyubov. In 1932, Bogolyubov, together with Academician N. M. Krylov, performed researches in the theory of power systems stability that were one of the first implementations of the theory of nonlinear oscillations in practice. In 1932, the Ukrainian Institute of Industrial Energy published the work of these authors on the issues of sustainability analysis of generators, which was the first attempt to solve nonlinear problems in the area adjacent to the automatic control theory. In 1937, Academician S. A. Lebedev developed the theory of artificial stability of synchronous machines. P. S. Zhdanov coauthored with Lebedev in writing a monograph 'The stability of parallel operation of power systems', which was the first work on these issues in the world.

In the second half of the 20th century, fundamental and applied researches of power systems were carried out in Ukraine by the scientific team of Institute of Electrotechnics (since 1963, the Institute of Electrodynamics) of the UkSSR Academy of Sciences. Lebedev and Tsukernik continued the investigations of V. M. Khrushchev on the development of technical devices of automatic control modes of electric power stations, primarily in the development and implementation of compounding devices of synchronous generators. This resulted in the development of industrial designs of high-performance compounding devices with selenium rectifiers, which were used for synchronous generators at power stations. Series of automatic excitation regulators were introduced on

power stations of different capacity and destination. Also in 1965, regulators such as PHA-64 were exported to the United Kingdom and other countries (VNLU, f 263, d 1, n 484, p 19).

The creation of small electronic computers at the Institute of Electrotechnics of the UkSSR Academy of Sciences under the lead of S. A. Lebedev, which was the first in the USSR and continental Europe, contributed to the development of several lines of research on the application of computing machines to solve engineering problems and operation of power systems. This is the study of power system stability, in particular, the unified power system of the USSR, issues on its automation and efficiency work improvement, development of analysis methods for complex power system modes, relay protection of power stations and power grids. In 1954–1956, studies on the use of computing machines in the modeling of complex power systems were conducted by L. V. Tsukernik and N. A. Kachanova for the first time in the USSR. In 1964, Tsukernik was the head of the Electrical Systems Simulation Department of the Institute of Electrodynamics, where for the first time in the USSR the industrial calculation program on computing machines with steady-state modes, dynamic stability, short circuit current and complex symmetrical emergency modes of power systems was carried out. The department developed and introduced into production the simulation methods and software for the first and second computer generation such as M-220 and BESM-4 (high-speed electronic computing machine) (VNLU, f 263, d 1, n 273, p 40).

The founding of the Department of Electrical Systems Automation, headed by I. M. Sirota, stimulated the development of scientific interest towards formulation of the foundations of theoretical basis and methods of increasing the reliability of electric power systems on the basis of new automatic control principles and relay protection; research into the short circuit processes to the ground in electrical systems; the development of new relay protection and emergency automation devices. Sirota with his team at the department were engaged in innovative research such as the development of the new methods of generators differential protection, methods of remote measurement for currents of high-voltage lines, and telecontrol systems for the wires of distributive networks (VNLU, f 263, d 1, n 703, 3 arc).

In 1968, the department was involved in the scientific study of current-measuring devices under the lead of B. S. Stogniy. The group was engaged in the development of measuring current and voltage converters, used for the operation of power systems as a measuring data sources, developing the theory, design principles and testing methods that became the basis for the creation of

innovative types of converters. In 1988, the department created a laboratory of programmable automation and protection systems, under the supervision of A. V. Kirilenko. The laboratory dealt with the automation design, with the use of computers and the electromagnetic part of the converters under different conditions (STA of IED, f 263, d 1, n 143, p 242).

Under the lead of G. I. Denisenko, a scientific school on the issues of transmission of electricity over a distance of direct and alternating current of shared networks was established at the department of the Lviv Polytechnic. Further research developments in the electrical systems and networks department at the Lviv Polytechnic was associated with the work of V. S. Perkhach, PhD, professor in technical sciences. In 1970, at the Electrical Systems and Networks Department at Lviv Polytechnic under his leadership the scientific and educational school of mathematical modeling in power industry was formed. The scientific work was aimed at the developing of a new scientific field associated with mathematical modeling processes and optimization of electric power systems with valve devices (SA of Lviv region, f R-120, d 28, n 266, p 32).

At the Kharkiv Polytechnic Institute (KPI), a number of studies were carried out under the lead of Professor V. G. Khlomsky. The research team of the electrical systems and networks department developed the theory of electrical network calculations. Professor V. N. Suleymanov, who was a student of V. G. Khlomsky, continued his research. Developments in the field of analysis theory, optimization and control of various modes of integrated energy systems and their interconnections should be noted. In 1962, the Department of Power Systems Automation was established at KPI under the initiative of Professor U. P. Gizil, the research topics of which were the development of methods and means of relay protection and automation of power systems. The Department of Automation of Power Systems at the KPI was established as late as in 2004; however, as research into the development of devices required controlling the process of production, transformation and distribution were carried out under the lead of V. U. Kizilov since 1960.

As can be seen from the above, during the second half of the twentieth century, studies in the field of optimization and automation of energy systems were separated into independent courses of scientific research, affecting a variety of issues, such as, for example, the development of devices and systems which enable the management of modes in normal and emergency conditions. Automation played an important role in the development of energy systems also in the research of American scientists. Further development of this course of research

was influenced by the wide introduction of electronic computers and control computing complexes. The National Dispatch Center of England, as well as the United States Integrated Systems Center with the help of electronic computers carried out management functions for the collection, processing and display of information.

Various research institutes in Russia such as the Moscow and Siberian Energy Institutes, the Novosibirsk State Technical University, the All-Union Scientific Research Institute of Electric Power Engineering, the Institute of Electronic Control Machines and others were engaged in theoretical and practical issues of automation of production, transmission and distribution control in normal and emergency modes without human participation. However, at this point the low quality of experimental apparatus manufactured from the USSR plants should be noted, making it difficult to obtain reliable data. The initiative to create automated dispatch control in the USSR was held by the scientific staff of the Energy Systems Institute named after L. A. Melentiev of Russian Academy of Sciences. The first studies on the development of mathematical methods and programs for forecasting, optimizing and reliability of energy in the USSR were conducted by the scientists of the Academy of Sciences of Ukraine. Scientific schools in the field of automation of energy systems were founded also in higher educational institutions of Russia, Uzbekistan, Estonia and Ukraine.

As mentioned above, in Ukraine, the beginning of research in the field of analysis, optimization and automation of normal and emergency modes of power systems was initiated by Academician V. M. Khrushchev. On his initiative, the Ukrainian Scientific Research Institute of Energy and the Department of “Electricity Power Transmission” were established at KPI in the first half of the twentieth century, where innovative research was carried out and the first scientific staff was qualified. In the second half of the twentieth century, the Institute of Electrotechnics (Institute of Electrodynamics) of the Ukrainian Academy of Sciences became the coordinator of research in this direction. The development of computer technology stimulated the formation of a new course of research—the development of methods of mathematical modeling and software tools for the analysis of modes and energy control systems under the lead of S. A. Lebedev and L. V. Tsukernik. In 1970–1980, new features of computer technology allowed solving significant problems. There was a powerful scientific school at the Institute of Electrodynamics at that time, its research focused on the calculation of transitional modes and stability of power system; the calculation and analysis of normal and emergency modes; the calculation of protection devices settings;

the analysis and forecasting of electrical loads; and the development of objectives for operational control modes.

Important research was also carried out by scientists of the Higher Electrotechnical School, especially by the scientific teams of the departments of Kharkiv Polytechnic Institute. The studies were conducted in close collaboration with scientists of research institutes and representatives of the production sector.

References

- Bobalo, U. Y.**, ed. (2009), *National University "Lviv Polytechnics"*, Kyiv: LLC Publishing House "Logos Ukraina".
- Glebova, I. A.**, ed. (1999), *History of Electrotechnics*, Moscow: Publ. MPEI.
- IED (n.d.), 'History,' Institute of Electrodynamics of NAS of Ukraine. Retrieved from <http://ied.org.ua/files/history-ied.pdf> [accessed Oct 2017]
- National Archives of Kiev.
- SA of Lviv – State Archives of Lviv region, f R-120, d 28, n 266, p 32.
- STA of IED – The Scientific and Technical Archives of the Institute of Electrodynamics of NAS of Ukraine, f 263, d 1, n 143, p 242.
- Stogniy, B. S.** (2007), 'On the ways of automating of electrical systems,' *Technical Electrodynamics*, no. 3, pp. 41–50.
- The Archive of National Technical University "Kharkov Polytechnic Institute".
- The Archive of National University "Lviv Polytechnics".
- Tverytnykova, O. E.** (2010), 'The origin and development of scientific and technical school of Professor P. P. Kopnyayev, Kharkiv: NTU "KhPI".
- VNLU – Archival Institute of National Library of Ukraine named after V. I. Vernadsky of National Academy of Sciences of Ukraine (Vernadsky National Library of NAS of Ukraine), f 263, d 1, n 484, 273, 703.
- Zgurovsky, M. Z. et al.**, eds. (1995), *Naris istorii* [Short history], Kyiv Polytechnic Institute, Kyiv: Naukova Dumka.