History of the Static Power Converter Committee

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SINCE the beginning of this century the American Institute of Electrical Engineers (AIEE), and later its successor, the Institute of Electrical and Electronics Engineers (IEEE), has maintained a leadership position in the promotion of static power converter equipment to meet the needs of industry. The history of the mercury-arc rectifier, mechanical rectifier, germanium rectifier, and the silicon rectifier is encompassed in this discipline which forms the basis for the solid-state power conversion technology in wide use today.

Engineering information concerning events and progress in the development, design, application, maintenance, and operating experience of rectifier and inverter equipment has been disseminated by the AIEE/IEEE in three broad ways: first, through the promotion of meetings and technical sessions for the presentation and discussion of technical papers. Following a review process, those deemed worthy of advancing the art are published in the AIEE/IEEE journals; second, by the organization and sponsorship of specialized conferences or seminars at periodic intervals; third, through the development, publication, and promotion of standards covering definitions, ratings, test codes, safety, and operating practices of converters and associated electrical equipment.

An early AIEE meeting on the subject of mercury-arc rectifiers was held at Columbia University in New York on April 12, 1901. At this meeting, Peter Cooper Hewitt gave a public exhibition to illustrate the principles of the mercury vapor lamp (and at the same time the mercury-arc).

With the rapid development of metal-tank mercury-arc rectifiers in commercial sizes and the large number of rectifier installations made during the period of 1925 to 1930 coordinating efforts began in the AIEE. Two results of these were 1) the formation in 1930 of a subcommittee on mercury-arc rectifiers under the auspices of the AIEE Committee on Electrical Machinery and 2) the beginning of work on standards on ratings and practices for mercury-arc rectifiers.

During the 1930's this subcommittee on mercury-arc rectifiers organized many technical sessions for the presentation, discussions, and publication of papers describing the latest innovations and improvements—and there were many. As mercury-arc rectifiers in sizes up to 3000 kW were developed many units were installed in railway service beginning about 1925 and continuing during the 1930's.

During the period of 1935-1940 many mercury-arc units began to be applied in electrochemical service for the production of aluminum, magnesium, chlorine, hydrogen, and other elements. Industrial dc power requirements of World War II were met by a tremendous expansion of mercury-arc converter installations.

As time went on mercury-arc rectifiers began to be applied to other power converter applications, such as frequency converters, mill drives, mining power supplies, high-voltage dc transmission, and research facilities such as particle accelerators. The lessons to be learned from these mercury-arc applications were later applied to solid-state technology.

There was of course a large increase in the number of engineers engaged in work related to rectifiers as a result of the many new installations. The need for a better understanding of the subject of rectifiers was recognized so work was begun on the drafting of standards. The first report on standards was presented to the AIEE in 1933. It was approved and transmitted to the American Standards Association (ASA) which issued the report in pamphlet form in 1934.

The Subcommittee on Mercury-Arc Rectifiers has changed its name and status a number of times during the past 50 years. But it has continued to play an active role in the promotion of technical sessions, conferences, and standards treating with rectifiers. Table I presents a chronological record of the organization and membership of the AIEE/IEEE committee on "Rectifiers" or "Static Power Converters."

An important activity of the committee has been the organization of conferences. These have been held at about five year intervals since 1952. They have provided an opportunity for members from both manufacturers and users to review and discuss the many aspects of application, design, manufacture, installation, operation, and maintenance. A list of the conferences on static power converters is given in Table II.

The changing technology of static power conversion is recorded in both the names of the committee and the titles of these special technical conferences. Examination of the subject matter of papers presented at the conferences reveals the rapid transition from mercury tubes to semiconductors in the decade 1955-1965 followed by an expansion of applications and an increasing diversity in power semiconductor devices, trends that are still underway.

At the 1952 conference the field was dominated by mercury-arc rectifiers of various types. One paper covered mechanical rectifiers and another dealt with metallic rectifiers, including copper oxide, copper sulfide, and selenium types of semiconductors. These had been developed during the 1920's and by series and parallel connection of cells into stacks, expanded into the area of high voltage and current. By today's standards these solid-state rectifiers were very bulky. Brief mention of the germanium rectifier hinted of things to come.

By the time of the 1957 conference silicon rectifiers had appeared, and with germanium and the older metallic rectifiers, obtained a majority in the number of papers. All these semiconductor rectifiers were diode devices and were often used in con-

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TABLE I
HISTORY OF AIEE IEEE COMMITTEE ON RECTIFIERS STATIC POWER CONVERTERS

AIEE		
1930	Beginning	
	Sponsor—Committee on Electrical Machinery	
	Name—Subcommittee on Mercury-Arc Rectifiers	
	Chairman—E. L. Moreland	
1940	Reorganization—transfer to Committee on Electronics	
	Chairmen, Committee on Electronics	
	* 1943–1944	S. B. Ingram
	1944–1945	W. C. White
	1945–1947	W. R. G. Baker
	1947–1948	C. H. Willis
	Chairmen, Subcommittee on Mercury Arc Rectifiers	
	Names not available	
1947	Reorganization—status change to full committee (Power Group)	
	Name—Committee on Electronic Power Converters	
	Chairmen	
	* 1947–1949	H. Winograd
	1949–1951	C. C. Herskind
	1951–1953	I. K. Dortort
	1953–1955	A. Schmidt, Jr.
1955	Reorganization—name change to Committee on Industrial Power Rectifiers	
	Chairman	
	1955–1957	J. B. Pitman
	1957–1959	J. K. Dillard
	1959–1961	C. A. Langlois, Jr.
	1961–1963	M. M. Morack
IEEE		
	1963–1966	F. D. Shaw
	1966–1967	C. S. Hague
1968	Reorganization—name change to Committee on Static Power Converters	
	† 1968	R. V. Wachter
	1969	A. Ludbrook
	1970	S. P. Jackson
	1971	W. H. Bixby
	1972	A. J. Humphrey
	1973	R. P. Stratford
	1974–1975	A. M. Curry
	1976–1977	C. J. Amato
	1978–1979	L. F. Stringer
	1980–1981	R. G. Hoft
	1982–1983	W. McMurray
	1984	R. G. Schieman

* Term of Office—Year July 1 to July 1.
† Term of Office—Calendar Year.

TABLE II
LIST OF CONFERENCES ON STATIC POWER CONVERTERS

AIEE	
1947	June 13—Montreal, PQ, Canada Conference on Operation of Mercury Arc Rectifiers
1949	April 11—Buffalo, NY Electron Tube Conference
Series of conferences sponsored by the Committee*	
1952	May 19–20—Pittsburgh, PA Electronic Converter Applications and Tubes
1957	June 4–5—Chicago, IL Rectifiers in Industry
1962	September 18–19—Columbus, OH Rectifiers in Industry
IEEE	
1965	November 1-3—Philadelphia, PA Industrial Static Power Conversion Conference
1972	May 8-10—Baltimore, MD IEEE International Semiconductor Power Converter Conference
1977	March 28-31—Lake Buena Vista, FL IEEE/IAS International Semiconductor Power Converter Conference
1982	May 24-27—Orlando, FL IEEE/IAS International Semiconductor Power Converter Conference

* *Note*: All conferences since 1957 were jointly sponsored by the Static Power Converter Committee (or its predecessor) and the Power Semiconductor Committee (or its predecessor) and joined in 1982 by the Industrial Drives Committee.

junction with saturable reactors to form magnetic amplifiers for control of the dc output. The triode mercury-arc rectifiers achieved control by firing angle delay and were still necessary for inversion or regeneration from dc to ac.

In 1962 only one paper on mercury-arc rectifiers was presented and silicon had displaced all the other semiconductor materials. The silicon controlled rectifier or triode thyristor introduced in 1958 is controlled by firing angle delay without the complexity of auxiliaries required by mercury tubes or the bulk of saturable reactors. Its penetration into the field of power conversion grew with the size of available devices from a couple of papers in 1962 to a majority in 1965 and dominance at the 1972 conference. The mercury-arc rectifier made a last stand in large valves for high voltage direct current (HVDC) power transmission, but has now been deposed from that by arrays of thyristors.

The advent of controlled power semiconductors made self-commutated converters practical in many new applications. While the use of capacitors to turn off mercury tubes was recognized early, and many circuit arrangements were devised in the 1930's, their complexity and cost drastically limited their applications. With thyristors and diodes these old circuits were revived, and many new commutating circuits were devised, leading to applications such as dc choppers for electric traction, adjustable frequency inverters for ac drives, fixed frequency inverters for uninterruptible power supplies, induction heating, and many others.

With silicon diodes and thyristors well established in traditional line- or load-commutated converters, the technical novelty shifted to self-commutation and special semiconductor devices developed for this purpose. At the 1977 and 1982 conferences, papers dealing with self-commutated converters, their application and their control predominated. Thyristors have diversified into bidirectional (TRIAC) devices, fast turn-off types, asymmetrical, and reverse-conducting as well as gate turn-off (GT)) varieties at the same time increasing in voltage and current rating. Power transistor converters which require no commutating capacitors early filled the lower power range of equipment and are now up to about 100 kVA. At higher power levels the GTO is displacing conventional thyristors with commutating circuits. For high switching frequencies, metal oxide silicon field effect transistors (MOSFETS) of in-

TABLE III
SUMMARY OF STANDARDIZING ACTIVITIES ON STATIC POWER CONVERTERS

AIEE	
1931	Subcommittee on Mercury Arc Rectifiers begins work on standards for mercury arc rectifiers.
1933	Subcommittee submits report on standards. Approved by AIEE and transmitted to ASA.
1934	ASA issues pamphlet "Report (Number 6) on Standards for Acceptance Tests of Metal-Tank Mercury Arc Rectifiers."
1940–1946	Subcommittee prepares revision to Report (Number 6) of 1934.
1946	AIEE publishes "Report on Proposed Standards for Pool Cathode Mercury-Arc Power Converters."
1949	ASA issues standard ASA C34.1-1949 American Standards for Pool Mercury-Arc Power Converters.
1954–1956	Subcommittee prepares revision of Standard of 1949.
1958	ASA issues revised standard ASA C34.1-1958 American Standard for Pool-Cathode Mercury-Arc Power Converters.
IEEE	
1968	USAS issues standard USAS C34.2-1968 Practices and Requirements for Semiconductor Power Rectifiers.

The present status of the Static Power Converter Committee work on standards is as follows.*

444–1973	Practices and Requirements for Thyristor Converters for Motor Drives, Part I—Converters for dc Motor Armature Supplies (C34.3-1973)
428–1981	Thyristor Alternating-Current Power Controllers (ANSI/IEEE)
519–1981	Harmonic Control and Reactive Compensation of Static Power Converters (ANSI/IEEE 83)
597–1983	General Purpose Thyristor dc Drives (Part II of 444–1974) 12/17/81 StB approved
P629	Semiconductor Power Rectifiers 12/12/75 PAR approved (revision) 1/12/83 draft completion and ballot (telephone advice)
P652	Review of the IEC Standard 146-2, Part II: Semiconductor Self-Commutated Converters 12/9/76 PAR approved 9/1/83 committee reactivated at the IAS winter meeting
P936	Self-Commutated Converters and guide for 12/17/81 PAR approved.

* *Note:* Extracted from the IEEE Standards Board Report dated December 1, 1983.

creasing size have become available. Devices incorporating features of both bipolar and field-effect transistors have recently been introduced.

In addition to the changes in power devices and applications, the static power converter engineer has also adapted to changes in control circuit components—from vacuum tubes and magnetic amplifiers to transistors, integrated circuits and microprocessors—and techniques—from phase control to pulsewidth modulation (PWM). All these developments have been accompanied by an expansion in the membership and activities of the Static Power Converter Committee. Since the first Industry Application Society IAS Annual Meeting in 1966, with nine papers in two sessions sponsored by the static power converter committee (SPCC), our contribution has grown to an average of 20 papers in four sessions during the last five years.

TABLE IV
COMMITTEE REPORTS

1)	ASA Report Number 6 issued June 1934 Report on Standards for Acceptance Tests of Metal-Tank Mercury-Arc Rectifiers
2)	AIEE Report Number 6 June 1946 Report on Proposed Standards for Mercury-Arc Power Converters
3)	AIEE Transactions Vol. 65 1948 Inductive Coordination Aspects of Rectifier Installations
4)	AIEE Transactions Vol. 67 1948 Mercury-Arc Power Converters in North America
5)	ASA C34.1 1949 American Standards for Pool-Cathode Mercury-Arc Power Converters
6)	AIEE Transactions Paper 49-271 1949 Rectifier Transformer Characteristics
7)	AIEE Publication 35 1950 Bibliography on Electronic Power Converters
8)	AIEE Transaction Paper 50-133 1950 Protection of Electronic Power Converters
9)	AIEE Transaction Vol. 50 May 1950 Inductive Coordination Aspects of DC Systems Supplied by Rectifiers
10)	AIEE Transaction Paper 53-288 1953 Water Cooling Systems for Mercury-Arc Rectifiers
11)	ASA C34.1 1958 American Standard for Pool-Cathode Mercury-Arc Power Converters

The AIEE/IEEE members have played a major role in the development of standards. They have long recognized the need for standards and the benefits to be derived from them. As a result they have taken a strong initiative to prepare and present material for standards through a democratic process. This has led to the issuance of rectifier standards by both the IEEE and American National Standards Institute (ANSI). Table III presents a summary of the results of standards activities in the AIEE/IEEE.

At the same time AIEE/IEEE members were delegates at meetings of the International Electrotechnical Commission (IEC) in many countries. They participated in these meetings in order that the IEC Standards might include an international viewpoint.

The AIEE/IEEE members have also contributed to the fund of useful information about power converters through the preparation of committee reports. A list of these is presented in Table IV.

From its beginning until the present date most of the work of the committee has been accomplished in its many subcommittees and working groups. These are too numerous to list and define here, but grateful credit should be given to the many dedicated individuals contributing to those working groups. At present, the SPCC includes seven technical subcommittees or working groups.

Members of the Static Power Converter Committee receiving Society recognition by being awarded the Industry Applications Society Outstanding Achievement Award include

1972	Boris Mokrytzki
1973	Robert V. Wachter
1974	Harold Winograd.

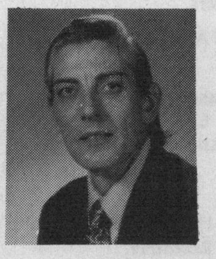
In 1973 Lysle W. Morton was awarded the IEEE Standards Medallion, which recognized his outstanding leadership in developing rectifier standards in both the IEEE and the International Electrotechnical Commission.

This report can only touch upon the extent of the fine work done by many of the AIEE/IEEE Members in the advancement and application of the industrial power converters. May the work of the Static Power Converter Committee be even more fruitful in the years to come.

C. Curtis Herskind (M'26–SM'40–F'48–LF'61) received the B.S. degree in electrical engineering in 1925 from the University of Denver, Denver, CO. In 1929 he graduated from the GE Advanced Engineering Program.

He later joined the General Electric Company on the Test Program. In 1930 he joined the General Engineering Laboratory, where he specialized in the development, design, analysis, and application of mercury-arc rectifiers. A major part of his work has been on large size power rectifier units for transportation, electrochemical, and industrial applications. These include electromotive propulsion, electrochemical pot-lines, steel rolling mill drives, and high-voltage dc-transmission. In 1938 he supervised the development and design of the first large size commercial pumped ignitron (3000 kW, 600 V) and in 1948 he supervised the development and design of a standard line of pumpless ignitrons. During this same period, he made special investigations of rectifier behavior and circuit action. From these studies he established a standard procedure for analysis of rectifier circuits, testing of rectifier tubes, determination of circuit duty, and assignment of ratings for rectifier tubes and tanks. From 1955 to 1965, he was a Consulting Engineer for the Power Electronics Section of the Tube Department of General Electric. In 1965 he transferred to the Electric Utility Engineering Operation, where he was Senior Application Engineer for the HVDC Transmission Engineering Section and was engaged in the specification and design of control for the Pacific HVDC Intertie until he retired in July 1968 from the General Electric Company. Since 1968 he has served as a Consultant on power electronics for a number of steel mills and other industrial firms. He became an Associate Consultant to Power Technologies, Incorporated in September 1973. In that capacity, he has been engaged in a project for the Department of Transportation featuring rectifiers.

Mr. Herskind has served on both technical and standardizing committees. He is a Registered Professional Engineer in the State of New York and holds 29 patents.



William McMurray (M'50–SM'60–F'80) was born in Los Angeles, CA, in 1929. He received the B.Sc. degree in engineering from Battersea Polytechnic, London, England, in 1950, and the M.S. degree from Union College, Schenectady, NY, in 1956.

Since joining General Electric Corporate Research and Development, Schenectady, NY, in 1953, he has been responsible for the development of solid-state power control and conversion circuits such as inverters, dc converters, power supplies and regulators, as well as electromagnetic control devices. He has also done work in the area of motor devices and computer simulation of converter circuits. He is the author of a book on cycloconverters.

Mr. McMurray was the chairman of the Static Power Converter Committee in 1982–1983.