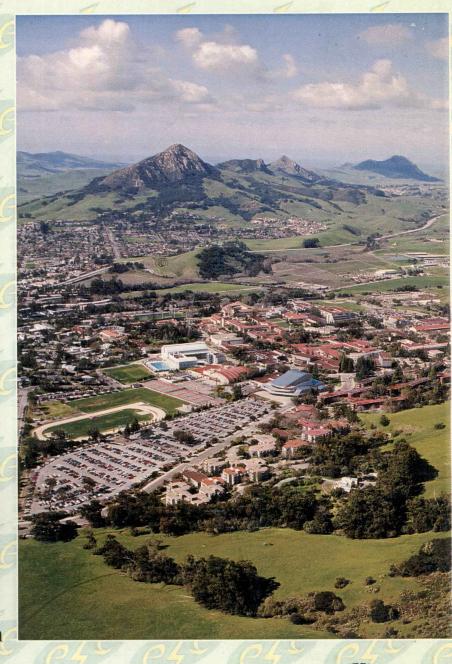
The Proceedings of the Thirty-first Annual

NORTH AMERICAN POWER SYMPOSIUM

October 10-12, 1999
California Polytechnic
State University
San Luis Obispo, California





IEEE Power Engineering Society





Proceedings

Thirty-First Annual

North American Power Symposium

October 11 - 12, 1999

California Polytechnic State University San Luis Obispo, California U.S.A.

Sponsored by

Power Engineering Education Committee of The IEEE Power Engineering Society

Electric Power Institute
Electrical Engineering Department
College of Engineering
California Polytechnic State University

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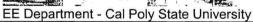


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College of Engineering – Cal Poly State University

Electrical Engineering





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About the Cover:

- Scenic view of Cal Poly and Bishop Peak, with Hollister Peak and the ocean in the distance. Photo by Forrest Doud
- The background is the Electrical Engineering Department Logo.

A Message from the Conference Chairman

Welcome to San Luis Obispo, California and Cal Poly for the 31st annual meeting of the North American Power Symposium. It is the first time for Cal Poly to host this symposium. It was a pleasure to organize and serve as the general chair of the 1999 Symposium.

The conference was initiated by a group of power engineering educators from Midwestern United States universities at an American Power Conference in Chicago. Named the Midwest Power Symposium, the first conference was held at the University of Minnesota in 1969. The main intent of the symposium was to allow graduate students and professors to present and publish research ideas and preliminary results without excessive time delay. Many of the presentations were and still are made by the graduate students, affording them wonderful opportunities to prepare for future careers.

After some years, the conference started to receive support from universities outside of the Midwestern United States, and hence, the name was changed to the North American Power Symposium (NAPS), effective 1986. Today this symposium attracts participants from all over the United States of America and abroad.

For almost 30 years, the conference theme has not changed and the goals of the conference remained the same. The purpose of the symposium, developed in 1969, is restated below:

The purpose of the Midwest Power symposium is to stimulate advanced scholarly work and more research activity in the field of Electric Power Engineering. This symposium is to be a forum where advanced students, their academic advisors, and participating engineers can present the results of their work, discuss the activities of their colleagues, and publish their technical accomplishments with a minimum time delay.

California Polytechnic State University is at San Luis Obispo, a pleasant, progressive city of about 43,000 on California's Central Coast, midway between San Francisco and Los Angeles. The city and university share a neighborly, small-campus, small-town feeling and one of the finest natural environments anywhere. Sparkling-clear air and a climate that's temperate year-round blend with majestic peaks, quiet valleys and the nearby ocean to create an exhilarating environment that's ideal for learning and growing. Cal Poly will celebrate its centennial anniversary in 2003; it has grown from an enrollment of 15 to about 16,000 students. The University has 6 colleges: Agriculture, Architecture & Environmental Design, Business, Engineering, Liberal Arts, and Science & Mathematics. About 4,000 of the 16,000 students are in the College of Engineering.

The Electrical Engineering Department offers the BS degree in Electrical Engineering (EE). The Computer Science Department and the Electrical Engineering Department jointly offer the Computer Engineering Program (CPE). In the Fall of 1998, enrollment in the EE Program was at 638 undergraduate and 29 graduate students.

The EE Department has 21 full time faculty and about six lecturers teaching in both the EE and CPE programs and involved in research in several areas. The main focus of the program is to prepare graduates for practice in professional engineering. Thus, Cal Poly's "learn by doing" philosophy is emphasized by integrating design throughout the curriculum in the numerous design-centered laboratories. In 1971 the EE Department established the Electric Power Institute (EPI). Several utility companies are EPI affiliate members; they support research in electric power engineering conducted at Cal Poly.

This year, as in previous years, we have used an electronic form of communication for the majority of the correspondence. Since time is always of the essence in arranging conferences, this form has proven to be very effective in accomplishing all tasks within the stipulated time and cost. Publication of the program and registration information on the World Wide Web has also proven to be useful.

The response we received to the Call for Papers for NAPS'99 was moderate. Fifteen parallel sessions, a panel session, and a banquet speaker have been scheduled for NAPS' 99. Five of the parallel sessions have six papers each and the rest have five papers each.

I would like to take this opportunity to recognize and extend my appreciation to Mr. C. John Essel and Bill Schwartz, Editors of the IEEE Power Engineering Review, for publicizing NAPS 1999 in the journal. Also, I would like to extend my appreciation to Mr. Tom Meng, Commissioning editor of Power Industry Development Magazine, for publicizing NAPS 1999 in the magazine. Special thanks go to the following organizations for providing financial support: The College of Engineering, Electrical Engineering Department, Electric Power Institute, IEEE (Central Coast Section), Thoma Electric, Nevada Power Company; Duke Energy, and National Science Foundation. Support provided by the National Science Foundation, Dean's office, EE department, EPI, and IEEE-Central Coast section will be used to reimburse student for their travel and lodging. Also, I would like to thank the Electrical Engineering department staff and the EPI staff for their support in making this conference a success. Thanks to all colleagues for their help in reviewing the papers and for their very helpful suggestions in the organization of the conference. I would like to extend my appreciation also to Mr. Forrest Doud for allowing us to use his photo on the cover of the proceedings. Finally, special thanks to Mrs. Diane Simoes, from Conference Services, for helping with the coordination of the Symposium and its financial management.

Once again, welcome to San Luis Obispo and have a wonderful time!

Ali Shaban Cal Poly State University, SLO August 1999

List of Host Institutions

Year	Host University	Location
1969	University of Minnesota	Minneapolis, Minnesota
1970	Iowa State University	Ames, Iowa
1971	University of Michigan	Ann Arbor, Michigan
1972	University of Missouri-Columbia	Columbia, Missouri
1973	University of Cincinnati	Cincinnati, Ohio
1974	University of Missouri-Rolla	Rolla, Missouri
1975	University of Akron	Akron, Ohio
1976	Kansas State University	Manhattan, Kansas
1977	West Virginia University	Morgantown, West Virginia
1978	University of Nebraska	Lincoln, Nebraska
1979	The Ohio State University	Columbus, Ohio
1980	Purdue University	West Lafayette, Indiana
1981	University of Illinois	Urbana, Illinois
1982	University of Wisconsin	Madison, Wisconsin
1983	Iowa State University	Ames, Iowa
1984	Drexel University	Philadelphia, Pennsylvania
1985	Michigan Technological University	Houghton, Michigan
1986	Cornell University	Ithaca, New York
1987	University of Alberta	Edmonton, Canada
1988	Purdue University	West Lafayette, Indiana
1989	University of Missouri-Rolla	Rolla, Missouri
1990	Auburn University	Auburn, Alabama
1991	Southern Illinois U. at Carbondale	Carbondale, Illinois
1992	University of Nevada, Reno	Reno, Nevada
1993	Howard University	Washington, D.C.
1994	Kansas State University	Manhattan, Kansas
1995	Montana State University	Bozeman, Montana
1996	Massachusetts Institute of Technology	Cambridge, Massachusetts
1997	University of Wyoming	Laramie, Wyoming
1998	Cleveland State University	Cleveland, Ohio
1999	Cal Poly State University	San Luis Obispo, California
2000	University of Waterloo	Waterloo, Canada

Organizing Committee

Ali Shaban, Chair Ahmad Nafisi, Co-Chair Taufik, Co-Chair

Diane Simoes, Conference Services Stephanie Allen, Electric Power Institute

PANEL SESSION: Electric Utility Deregulation and Restructuring

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