Recent Developments in FACTS Technology

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With some transmission lines becoming loaded to their capacity and new lines being hard to site and build, the ever-growing need for transporting more electricity can be met either by installing new transmission lines or by using the existing ones in a more efficient way. The latter approach is to maximize the active power flow that generates revenue while minimizing the reactive power flow that contributes nothing to the useful energy delivered.

The power industry's quest for the *most economic way to transfer bulk power along a desired path* can only be achieved through the independent control of active and reactive power flow in a transmission line. Traditional solutions, such as shunt inductor/capacitor, phase-shifting transformer, and series inductor/capacitor affect both the active and the reactive power flow in the transmission line simultaneously. With the use of Voltage-Sourced Converter (VSC)-based Unified Power Flow Controller (UPFC), the active and the reactive power flow in the line can be regulated independently. Since the field demonstration of the world's first UPFC in 1998, another FACTS controller, namely Sen Transformer (ST), has been proposed. In contrast to the UPFC, which uses a large number of solid-state switching devices, the ST uses time-tested components, such as transformer and load tap changers, but provides the same independent active and reactive power flow control as the UPFC at a much lower cost.

The objectives are to give a background on traditional power transmission technology and discuss new techniques that utilize the transmission lines most effectively. The workshop covers various types of Flexible Alternating Current Transmission Systems (FACTS) controllers and their usefulness in power system applications. Various modeling techniques of FACTS controllers are briefly discussed. The results from the simulation are compared with those from the field measurements.

This presentation is of particular interest to all power-engineering professionals. The required background includes an electrical engineering degree with familiarity in power engineering terminology.

The workshop is organized in the following way.

- Introduction
- Voltage-Sourced Converter (VSC)
- Installation of World's First UPFC
- VSC-based technology
- Simulation and field results
- Special applications of VSC-based technology
- Sen Transformer

About the Presenter:

Kalyan K. Sen received B.E.E, M.S.E.E, and Ph.D degrees, all in Electrical Engineering, from *Jadavpur University*, India, *Tuskegee University*, USA, and *Worcester Polytechnic Institute*, USA, respectively. He has spent 20 years in academia and industry. He was a member of the FACTS development team at Westinghouse Science & Technology Center in Pittsburgh, USA. He contributed in all aspects (conception, simulation, design, and commissioning) of FACTS projects at Westinghouse. Dr. Sen conceived some of the basic concepts in FACTS technology. He has many publications in the areas of FACTS and power electronics. Currently, he is a Fellow Engineer at the Curtiss-Wright Electro-Mechanical Corporation (formerly Westinghouse) in USA where he is engaged in power electronics applications research. His interests are in *Power Converters*, *Control*, *Electrical Machines*, and *Power System Simulations and Studies*. He is a licensed Professional Engineer.

Dr. Sen, a Senior Member of IEEE, has served the organization in many positions. In 2003, he re-established the Pittsburgh Chapters of the Power Engineering Society and the Industry Applications Society. Both Chapters received the "Outstanding Large Chapter" awards for the year 2004. Under his Chairmanship, the Pittsburgh Section received the "Outstanding Large Section" award for the activities in 2005. For the last six years, he has been serving as an Editor of the Transactions and a Distinguished Lecturer.

Sample Publications:

- K. K. Sen and M. L. Sen, *Comparison of the 'Sen' Transformer with the Unified Power Flow Controller*, IEEE Trans. Power Delivery, vol. 18, no. 3, pp. 1523–1533, Oct. 2003.
- K. K. Sen and M. L. Sen, *Introducing the Family of 'Sen' Transformers: A set of Power Flow Controlling Transformers*, IEEE Trans. Power Delivery, vol. 18, no. 1, pp. 149–157, Jan. 2003.
- K. K. Sen and A. J. Keri, *Comparison of Field Results and Digital Simulation Results of Voltage-Sourced Converter-Based FACTS Controllers*, IEEE Trans. Power Delivery, vol. 18, no. 1, pp. 300–306, Jan. 2003.

Sample Patents:

- K. K. Sen and M. L. Sen, Multiline Power Flow Transformer for Compensating Power Flow Among Transmission Lines, U.S. Patent No. 6,841,976 (January 11, 2005).
- K. K. Sen and M. L. Sen, Versatile Power Flow Transformers for Compensating Power Flow in a Transmission Line (Series-Compensating Power Flow Transformer), U.S. Patent No. 6,420,856 (July 16, 2002).
- K. K. Sen and M. L. Sen, Versatile Power Flow Transformers for Compensating Power Flow in a Transmission Line, U.S. Patent No. 6,396,248 (May 28, 2002).
- K. K. Sen and M. L. Sen, Versatile Power Flow Transformers for Compensating Power Flow in a Transmission Line (Limited Angle Power Flow Transformer), U.S. Patent No. 6,384,581 (May 7, 2002).
- K. K. Sen and M. L. Sen, Versatile Power Flow Transformers for Compensating Power Flow in a Transmission Line (Shunt-Compensating Power Flow Transformer), U.S. Patent No. 6,335,613 (January 1, 2002).