Understanding Power Electronics in Contemporary Power Systems (Incorporating Renewables/Storage, Reliable Delivery and Efficient End-Use)

1. Overview:

The objective of this fast-paced top-down tutorial is to present 1) the role of *Power Electronics* in Contemporary Power Systems that Integrate Renewables /Storage, Reliable Delivery and Efficient End-Use, and 2) to describe the operation of *power electronics* converters that facilitate the required interface.

The role of power electronics will be described in generation, delivery and efficient end-use:

A. There is increasing emphasis on generating electricity using renewable sources such as wind and photovoltaics. There is also a great need for energy storage at the utility-scale, for which solutions are being investigated.
B. Reliable delivery methods increasingly use HVDC transmission systems and FACTS devices such as SVC/STATCOM, TCSC etc. These are needed for voltage stability, which was not a serious issue in the past.
C. Power Quality is a concern due to the proliferation of power electronics based loads.
D. Efficient end-use requires variable-speed drives and new types of lighting.

In the second part of the tutorial, the operation of power electronics converters in these interfaces will be described in a very clear and concise manner.

This tutorial will be useful for **all** attending the PES General Meeting for the following reason: The nature of power systems has changed over the years. Many attendees like high-level managers and many power engineers educated sometime ago were never exposed to these topics that are critical in contemporary power systems. Unfortunately, the current graduates are also not taught these because the curriculum followed in most universities, with a few exceptions, has not changed to take contemporary practices into account.

2. Summary of Topics:

This tutorial in the beginning will emphasize the role of power electronics in contemporary power systems, and then will describe the power system operation. In doing so, it will describe the following applications:

Part 1: Role of Power Electronics

- Generation using Renewables
  - Wind
  - Photovoltaics
  - Fuel Cells (using hydrogen from electrolysis of wind-derived electricity)
- Storage

- Flywheels
- SMES
- Batteries such as NaS Batteries

- Reliable Delivery
  - HVDC
  - FACTS
    - SVC
    - TCR
    - STATCOM
    - UPFC
    - D-SMES
    - TCSC

- Efficient End-Use
  - Variable Speed Drives
  - Lighting using CFLs and LEDs
  - Switch-mode Power Supplies

- Power Quality
  - Unity Power factor Correction Circuits
  - Dual feeders
  - UPS
  - Dynamic Voltage Restorers

Part 2: Power Electronics Operation

- Solid-Sate Devices
- Thyristor Converters
- Pulse-Width Modulated Switch-Mode Converters

The attendees will get a notebook consisting of approximately 250 slides printed on paper and also on an accompanying CD.

3. Organization of the Tutorial:

This concise tutorial is organized to present the understanding of power electronics – its role in contemporary power systems and understanding its operation. How much is derived by an attendee will depend on his/her background. For example, high-level managers who may have a background in another area, other than EE, will appreciate what can be done. Utility engineers working in their narrow specialty will understand alternative ways of doing things and the academics in the audience will be able to potentially reform their courses to emphasize the contemporary topics.

Topic	Time Period
Role of Power Electronics: Generation using Renewable, Storage, Reliable Delivery, Efficient End-Use, Power Quality Concerns	1 hr
Solid State Devices and Thyristor Circuits and Converters	1 hr
Operation of Thyrisor Converters in HVDC and Various FACTS Devices	½ hr
Understanding Switch-Mode Converters	1 hr
Application of Switch-Mode Converters in Various Applications	½ hr

4. Instructors:

- Prof. Ned Mohan, Dept of Electrical and Computer Engineering, University of Minnesota
- Prof. Bruce Wollenberg, Dept of Electrical and Computer Engineering, University of Minnesota
- Dr. Narain G. Hingorani, Consultant (Consultant, Retired VP – EPRI)

Biographies:

Ned Mohan is Oscar A. Schott Professor of Power Electronics in the Department of Electrical Engineering at the University of Minnesota, where he has been teaching for 31 years. He has written five textbooks; one of them is translated into several languages. He is a Fellow of the IEEE. He received the Distinguished Teaching Award of the Institute of Technology, and the Morse-Alumni Distinguished Teaching Award conferred by the University of Minnesota.

Bruce F. Wollenberg received his Bachelors degree in Electrical Engineering and Masters degree in Electric Power Engineering from Rensselaer Polytechnic Institute in 1964 and 1966 respectively. He was subsequently awarded a Ph.D. in Systems Engineering from the University of Pennsylvania in 1974. He was employed in industrial positions from 1966 to 1989 working with companies supplying computer control systems to the electric power industry. He became a full professor of Electrical and Computer Engineering at the University of Minnesota in 1989. Professor Wollenberg is a member of the National Academy of Engineering and a Fellow of the IEEE. He was a recipient of the IEEE Third Millennium Medal in 2000, the IEEE PES Outstanding Power Engineering Educator Award in 2002, and the HKN Outstanding Teaching Professor Award for the 2002-03 year. He is the coauthor with Allen Wood of the Wiley textbook **Power Generation Operation and Control**.

Narain G. Hingorani: In 1995, following a twenty year career at EPRI, including last 5 years as Vice President of Electrical Systems, Dr. Hingorani retired from EPRI and started his own consulting in Application of Power Electronics in Power Systems. Prior to joining EPRI, Dr. Hingorani spent 6 years at Bonneville

Power Administration; his responsibilities included the commissioning of the Pacific DC Intertie and Series Capacitor compensation. Presently Dr Hingorani provides consulting services in the area of development of power electronics and devices and application of power electronics to transmission, distribution, industrial power and marine power system.

Dr. Hingorani is credited with originating the concepts of Flexible AC Transmission System (FACTS) and Custom Power, which are now well known and are expected to revolutionize future ac power transmission and distribution systems, respectively. In 1985, Dr. Hingorani was presented the Uno Lamm Medal by the IEEE Power Engineering Society for outstanding contributions in High Voltage Direct Current Technology, and later received the 1995 IEEE Lamme Gold Medal for leadership and pioneering contributions to the transmission and distribution of electric power. In 2004, In recognition of Dr. Hingorani's pioneering of FACTS and Custom Power technologies, IEEE Power Engineering Society decided to name its FACTS and Custom Power Awards as "Nari Hingorani FACTS Award" and "Nari Hingorani Custom Power Award". He is a Life Fellow of IEEE. In 1988, Dr. Hingorani was elected to the National Academy of Engineering of the USA. From 1988 to1996, he was Chairman of prestigious CIGRE Study Committee 14: DC Links and Power Electronics. From 1998 -2004, he was a member of the IEEE Foundation Board. From 2002 he has been a member of National Academy panel for technical assessment of the Army Research Lab. R&D Program on Sensors and Electron Devices.