Presentations Abstracts

Keynote Address I:

Ned Mohan, "Research and Reinventing Electric Power Curriculum with Sustainability Focus"

This presentation will describe the changing climate because of us and the need for urgent action. It will describe the power-electronics based research at the University of Minnesota initiated with the ONR-funding and now being conducted to interface renewable energy sources with the grid.

The second part of this presentation will describe a large number of courses in the electric power curriculum that have been developed and their contents uploaded to www.cusp.umn.edu.

This presentation will also describe the possibility of offering these courses online, taught by web-based instructors, towards a master's degree.

Keynote Address II:

Tore Undeland, "Wind Energy, onshore, offshore and floating offshore. State of the art: System Overview, Generators and Grid Integration"

Short on wind energy physics, production is proportional to the cube of wind speed, it is important to find sites with good wind. Why wind turbines survives winter storms, while wave energy converters break down? Example: Just now, a 1.400 million USD wind farm of 1000 MW is under development along the coast West of Trondheim in Mid-Norway. It will produce 3.4 TWh annually, which is equivalent to full production in 3400 hours a year.

In 2016 10,923 MW were installed onshore in Europe, and 1,567 MW were installed offshore.

Cost of onshore wind energy has dropped 41 % from 2008 til 2015. Offshore wind energy has double cost, but is used a lot outside UK, Germany and Denmark due to not enough land for onshore wind turbines.

Today the North Sea cables are point to point connecting offshore wind turbines and renewable hydro power to the oil platforms. The offshore oil platforms need 50 to 100 MW. Also the land-to-land transmissions are done by separate cables. Research is done on how to integrate these to a multi-terminal HVDC system.

For your information:
From: https://windeurope.org/about-wind/statistics/european/wind-in-power-2016/

2016 annual figures

- 12.5 GW of new wind power capacity was installed and grid-connected in the EU during 2016, a decrease of 3% compared to 2015 annual installations. 10,923 MW were installed onshore, and 1,567 MW were installed offshore.
- Wind power installed more than any other form of power generation in Europe in 2016. Wind power accounted for 51% of total power capacity installations.
- Renewable energy accounted for 86% of all new EU power installations in 2016: 21.1 GW of a total 24.5 GW of new power capacity.
- With almost 300 TWh generated in 2016, wind power covered 10.4 % of the EU's electricity demand.

Session I:

- *Prasad Enjeti "Teaching Power Electronics with an Emphasis on Renewable Energy Integration*

  In this presentation, power electronic converter, inverters and multilevel inverters that are essential for renewable energy integration to the electric grid will be covered. Several new ways to teach with technology will be explored.

- *Steve Völler, "A new course in design of smart power grids with emphasis on solar PV and microgrids at NTNU"*

  The modernization of the electric power grid in the coming years is known under the name Smart Grid. The Smart Grid is characterized by new technologies such as distributed energy sources, energy storage, electric vehicles, smart meters, sensors, automation, power electronics and digital operation. The future grid is a complex system of systems, where the benefits of digitalization are used to amplify and speed up the green energy shift, without compromising the reliability of the system. Significant changes in the primary energy sources used to generate electricity are taking place in many countries; even in Norway, a northern country with low sun and lots of hydropower, solar PV is booming and may eventually become the cheapest of alternatives also here. To answer the needs for increased competence in this regard in the Norwegian energy sector and industry, the Department of Electric Power Engineering has recently established a new course in Design and Operation of Smart Grid Power Systems. The emphasis is on solar PV and microgrids, and considers both technical and economic aspects of the developments. The aim of the course is to give our candidates competence that will lead to innovation in the energy sector. The talk will describe the potential for solar PV in Norway and other parts of the world, and describe the contents of and ideas behind the course. The speaker will welcome feedback and discussion on the course.
  The course description in NTNU's course catalog can be found here:
  http://www.ntnu.edu/studies/courses/TET4175#tab=omEmnet

Panel discussion I:

- *Rao Konidena, "Integration of Renewables at Regional Transmission Organization (RTO): Midcontinent ISO experience"*

  MISO is an independent system operator, and regional transmission organization. We operate in 15- US states including City of New Orleans and Canadian province of Manitoba who is our coordination member. We are regulated by Federal Energy regulatory commission and also come under North American Electric Reliability Corporation for reliability compliance purposes. Our transmission owning members formed MISO under an agreement. Geographically we cover Manitoba Hydro in the north to parts of Texas in the South. Our key load centers are Minneapolis-St Paul area, Madison, St Louis, and New Orleans. With headquarters in Carmel, Indiana we have control centers in Eagan, MN and Little Rock, AR and a planning office in New Orleans.

  Our peak load is approx. 127,000 MW with total generating capacity around 175,000 MW. Traditionally we had lot of coal in the mix. Our current energy mix is: 46% of coal, 27% of gas, 16% of nuclear, 8% of wind, 2% of hydro and 2% of others. Natural gas is cheap as you might have heard in US, as a result we expect energy % from gas to increase upto 40% in future. 11,000 MW of gas in the interconnection queue. Our current wind is 16,000 MW with a high of 13,000 MW. We project 23-25 GWs of wind by 2025. There is 34,000 MW in the queue. Solar is starting to show up at MISO; Xcel Energy just went online with 100 MW of grid scale solar in MN. We have approx. 9,000

MW of solar in the interconnection queue with majority in the South region (Louisiana and Arkansas). We have 140 MW of energy storage in the queue.

Rao's presentation will cover MISO's experience integrating renewables in multi-state jurisdictions. With the emergence of storage and distributed energy resource technologies, transmission planning is changing. Rao's presentation will address the challenges associated with modeling renewables in 5-10-15 year out planning models and the need to seek stakeholder input.

- *Subhashish Battacharya, "Solid State Transformer (SST) as Energy Router for DER (Distributed Energy Resources) and DESD (Distributed Energy Storage Devices) Integration to the Grid"*

  Enabling Distributed Energy Resources (DERs), and Distributed Energy Storage Devices (DESDs) integration through Solid State Transformer (SST) on distribution grids. The new concept of SST being used as an "Energy Router" to enable and manage higher penetration of renewable energy sources to the grid will be enumerated. This discussion will focus on the functionality and specifications of SST to enable not only power management functions but also energy management functions, effectively enabling the SST to provide multi-functionality in integration of DERs and DESDs and also enable both AC and DC port plug-ins. The SST functions as a "multi-plug" to manage all distributed resources connected to it. Multiple SSTs can be coordinated to provide both AC and DC microgrid functions.

  SST also enables volt-var and volt-watt optimization on distribution grid and provides system level efficiency improvement. Case studies with higher PV penetration and it modelling in RTDS with HIL will provide used cases.

Session II:

- *Siddharth Raju and Ned Mohan, "Hardware Demo"*

  With the present ONR funding, a simulation platform has been developed which is similar to well-known platforms in use at present. It used to control an extremely low-cost DSC/microcontroller such as TI's 32-bit Delfino. The entire package is **two orders of magnitude** *cheaper than the present solutions*. A hardware demo of this controller will be presented, for example, to vector-control of an induction motor drive.

- *Kjell Sand, "The NTNU Smart grid laboratory – designed to support education, R&D, demonstration and innovation of next generation smart and sustainable power systems"*

  The laboratory is a **system oriented** laboratory providing state-of-the-art infrastructure for R&D, demonstration, verification and testing over a wide range of Smart Grid use cases. As future power systems will include more intelligence and communications as well as new hardware and software, the system will develop towards a more complex system of systems that need to be tested and verified in university and industry labs as well as living labs.

  The laboratory concept will be described. In brief, a specific feature of the laboratory is the opportunity to integrate real-time simulations and physical power system assets (hardware-in-the-loop) with ratings up to 200 kVA, 400 V AC or 700 V DC. The application areas / domains supported by the lab are:

  - Smart transmission grids
  - HVDC grids
  - Smart active distribution grids
  - Micro grids

- Integration of Smart Grids, Smart houses and smart industries
- Integration of renewables (large scale, DG)
- Smart Grid and home automation
- Smart electricity use
- Electrification of transport
- Energy storage in Smart Grids
- Energy conversion in Smart Grids
- Power system stability in Smart Grids
- Monitoring, control and automation in Smart Grids
- Communication technologies for Smart Grids
- Information security and privacy in Smart Grids

Session III:

➢ *Tore Undeland, "Norwegian policy for electric cars / plan for reduction of CO2 emissions in transport"*

A typical gasoline car emits 2 ton CO2 per year. In Norway transport is the source of 25 % of CO2 emission, in the world 50 % of CO2 emissions are from transport.
Norwegian policy for electric cars / plan for reduction of CO2 emissions: Due to many incentives, Norway has the highest number of electric cars per capita. Also electric buses will soon be introduced.
Technologies for electric cars will be described. The cost of Li batteries was reduced by 73 % from 2008 to 2015.

➢ *Roy Nilsen, "Innovative hybrid and battery powered ships"*

The marine transport accounts for about 10% of the world's yearly energy consumption. To reduce the emission of Green House Gases (GHG) new solutions are required. Emission Controlled Areas (ECA) are defined, where strong limitations in emissions are defined. This means that new solutions have to be developed even in marine industry. As in the automotive industry, parallel and serial hybrid vessels are developed. The solutions are hybrids, plug-in hybrids and pure Electrical. To reduce emission in the Norwegian fjords such type of Shuttle ferries are required. Typical 70 % of all ferries in Norway can preferably be either pure electrical or plug-in hybrids. To be able to meet the cost target innovative and cost effective solutions have to be developed. This requires optimal hull-designs as well as propellers, but also an optimized power system. The presentation could/will cover key tasks to be evaluated/ executed by an electrical engineer:

- Analyzing operation profiles
- Type of energy source; Hydro Power, Diesel, LNG and Fuel Cells
- Combination of Energy sources and Energy Storage devices
- Life time calculations of batteries
- Efficiency/loss calculation of the components in the power system
- DC versus AC distribution system, including redundancy
- Distributed DC system versus DC Hub based power system
- Charging system: Wireless Chargers and Mechanical Plug-based
- Energy saving in hybrid ships by multiple Diesel-generator sets. These Diesel-gen sets could be distributed all over the ship, or even in containers.
  Thus also the reliability and time to repair will be improved.

Please note that power system on-board is an autonomous system, i.e, very similar to a micro-grid. This means that experience from the marine industry could be utilized on-shore.