Basics on Power Systems and Power Distribution & Selected Issues on Smart Grids and Electric Vehicles
Focus of the Lecture Today

- Urban Community
  - Consumption
    - Transportation
    - Heating & Cooling
    - Electricity
- Planning
- Energy Technology & Infrastructure
  - Power Distribution
    - Solar Energy
    - Wind Energy
    - Micro Co-Generation
    - Heat Pumps
    - Biomass Utilization
    - District Heating
    - Storage Systems
- Methods
  - Forecasting
  - Life Cycle Assessment
Topics Covered Today

PART I:
• Power Grid Basics
• About Smart Grids
• Vehicle to Grid Power

PART II:
• Energy System Models
Basic Principles in AC Power Systems

- Power system can be visualized as a large system of connected synchronous pendulums
  - Generation speeds them up, load drags them down

**Generation**
- Balancing large unit(s) with generators
- Synchronous
- Maintains system stability

**Transmission**
- Through cables
- Primary and secondary (voltage & power flow)
- Substations
- Radial or network

**Load**
- Typically passive
- Dependent on power availability
- Generates all end user services
This lecture is complemented with reading material on these topics:
- Smart Grids
- Vehicle-to-Grid concept
Power Grid Basics
Grid Structure

Transmission grid
- High and extra high voltage part of the grid (HV)
  - Finland: 110, 220, 400 kV
- Looped topology
- Automated safety systems
- Remotely controlled system adjustments
- Redundant structure

Distribution grid
- Medium voltage (MV) and low voltage (LV) parts of the grid
  - Finland: 20, 1, 0.4 kV
- Radial topology
- Mostly automated safety systems
- Mostly manual system adjustments
Nordic HV Grid

Urban LV Grid
Electrical Substations and Transformers

- Mediator between different voltage levels
  - Substation: HV-MV
  - Transformer: MV-LV
- Has automated safety switches
- Has tap changer mechanism
  - Transformer: manual
- Substation has a significant investment cost
Transmission Grid

Extra High Voltage
275 kV to 765 kV
(mostly AC, some HVDC)

High Voltage
110 kV and higher

Transmission Grid

Distribution Grid
Distribution Grid

- Rural Network
  - ~400 kW Farm
  - ~5 MW substations

- City network
  - Low Voltage (50 kV)

- Wind Farm
  - Extra High
  - High
  - Medium
  - Low Voltage

- City Power Plant
  - up to ~150 MW

- Industrial Customers
  - ~2 MW

- Solar Farm
Additional Content for Inspiration

- TED talk by Justin Hall-Tipping: ”Freeing energy from the grid” (17 min)
  - [http://www.ted.com/talks/justin_hall_tipping_freeing_energy_from_the_grid.html](http://www.ted.com/talks/justin_hall_tipping_freeing_energy_from_the_grid.html)

- TED talk by Eric Giler: ”Wireless electricity” (10 min)
About Smart Grids
What is Smart Grid?

- Electric network with advanced communication and information gathering infrastructure
  - Active monitoring of loads and all sources of generation
  - Improved coordination of all actors and stakeholders

- Improvements that Smart Grid brings:
  - Improved efficiency, system reliability, and system stability
  - Lesser environmental impacts from the system.
  - Better capacity to deal with small scale distributed power generation (small renewables, micro-CHP, etc.)
Grid Getting Smarter

• Smartening process is an ongoing process
  - Smart technologies are improving all the time
  - Increasing degree of smart technology implementation

• Includes a wide range of technology improvements
  - Communication equipment
  - Sensor equipment
  - Power conditioning equipment
  - Improved methods for transmission
  - Grid management equipment
  - Metering equipment
  - Customer-side equipment
  - Charging of electric vehicles
Grid Getting Smarter

Figure 2: Smartening the electricity grid

Source: IEA (2011a).
The Transition in Hierarchy

Today’s hierarchical power system

Fully realized smart grid
Japanese Smart Grid Concept

![Ubiquitous Power Grid Diagram](Image)
Vehicle to Grid Power
What is “Vehicle to Grid” (V2G) Power?

- Electric Drive Vehicles (EDV) provide power to grid when parked
- EDV can be many things:
  - battery–electric vehicle, fuel cell vehicle, or plug-in hybrid
- EDV:s can have several functions:
  - Battery in EVD is charged at times of low demand
  - Battery is discharged when needed
  - Fuel Cells can generate power when needed
  - Plug-in Hybrid can act in all modes
The Traditional Roles of EDV:s
EDV:s in V2G Power Concept
What is Required for V2G?

- Connection to the grid for electrical energy flow
- Control or logical connection necessary for communication with the grid operator
- Controls and metering on-board the vehicle
Functions of V2G Power

- Providing power at peak consumption times
- Acting as "Spinning Reserves"
- Providing other services for system regulation
- RESULT: EDV:s act as system-wide storage units
How V2G Use of EDV:s Balances Electric Loads

PHEV = Plug-in Hybrid Electric Vehicles