Energy Management & Control for the Evolving Smart Grid
EU-USFOE-Symposium

Dr. Cherry Yuen, ABB Switzerland Ltd, 3-5 Nov 2011, Irvine, CA
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  - HVDC Grids
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- Pilot Projects
Introduction
Hierarchy of Electric Power System
HV Transmission to LV Distribution

1. High voltage transmission level, >110 kV, meshed grid

2. Medium voltage distribution level, 6-35 kV, radial grid

3. Low voltage distribution level, <1000 V, radial grid

4. Low voltage household level

Large generating companies
Transmission system operator
Independent Power Producers
Distribution system operator
Small scale generation
Consumer

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Landscape of Players & Actors
Deregulation Vs Re-regulation

Regulator

Market System Operator (MSO)
Transmission System Operator (TSO)
Independent System Operator (ISO, US)
Distribution System Operators (DSO)

Generation Companies
Retailers
Energy Traders
Distributed Generation (DG) Producers
Industrial & Household Loads
Balancing Responsible Parties (BRP)

Regulated Players
Deregulated Players
Landscape of Players & Actors
Focus on Network Operations

- Transmission System Operator (TSO)
- Distribution System Operators (DSO)

- What they do?
- How they do it?
- How they interact with others?

in both current and futuristic scenarios
Network Operation Nowadays
Network Operation
Transmission & Distribution

- **Transmission**
  - Centralized approach (EMS)
  - Meshed topology for additional reliability
  - Objectives:
    - Security of supply: voltage, angle, frequency stabilities
    - Failures can lead to blackout

- **Distribution**
  - Centralized (DMS) & decentralized (Substation or further down the hierarchy) approaches
  - Mostly radial topology for costs reduction
  - Objectives:
    - Reliability (SAIDI, CALDI, etc.)
    - Power quality
    - Failures lead to local outages
Balance of Supply and Demand
A 24/7 Job

Bilateral Contracts / Tenders

Day-ahead Markets

Intra-day Markets / Imbalance Markets

Reduction of Forecast Errors

D-1

Start of Physical Transactions

D

Preventive Methods

Curative Methods

$\implies$ imbalances

animated slide

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Frequency Reserves
How TSOs keep real-time balance of supply & demand

Source: entso-e Operation Handbook

entso-e: European Network of Transmission System Operators for Electricity (former UCTE)
Challenges from Renewables
Challenges from Wind Energy # 1
Unpredictability

Without wind spilling or –ve reserves:
\[ P \rightarrow + \]
\[ f \]
\[ -\Delta P \rightarrow -\Delta f \]

In the “business-as-usual” case we would see much more such deviations in both directions.

Frequency excursion of the UCTE system April 2005
Source: SwissGrid (Former ETRANS)
Challenges from Wind Energy # 2
Intermittency

- Low capacity factor ~ 40% for offshore wind
- Very often producing during night time: low demand!!!

In the “business-as-usual” case wind production could become bigger than total demand
=> Zero or negative prices in some markets

animated slide
Challenges from Distributed Generation
Change of Flow Pattern

Flow from DG is going upstream in LV network

Flow from DG is going upstream in MV network

In the “business-as-usual” case this would lead to higher losses and voltage excursion at specific locations of the network.
Possible Remedies
Power Balancing using HVDC Grids
Imbalance Netting

- Imbalances resulting from forecast errors can be exchanged between the different nodes with a MT-VSC-HVDC setup
- One possible scenario:
  - Actual wind output is higher than forecast => surplus
  - Other areas can have deficits at the same time
  - MT-HVDC can be used for real-time power balancing (see animation)
- System imbalances can be reduced:
  - Enhanced system security
  - Reduced use of other reserves
- Better benefits with higher number of nodes => HVDC Grid
One possible application of energy storage for wind energy integration is to firm the daily output capacity of the wind facility. This is equivalent to maximizing its daily minimum power output. This can reduce intermittency of wind energy and render the wind farm more like a traditional dispatchable generation plant.
With industrial DSM (Demand Side Management) one can shift the peak load to low demand period(s) for “peak shaving” or to adjust the load curve to fit the output of DG.

- This can be motivated either by financial or technical objectives.
- In a regulated regime or vertically integrated environment the network operator will manage the demand response directly.
- In a deregulated regime the industrial plant operator can participate into the markets either directly or through a demand response aggregator (see animation).
MicroGrids can operate in islanded mode in case of faults in the main grid.

More often they are connected to the main grid.

Within the same MicroGrid controller one can implement the functionality to provide frequency reserves.

Distribution grids start to provide system services for the TSO.

=> a natural tendency because of the increase of distributed generation.
Pilot Projects
**Example Pilot Projects – Distribution Networks Involving ABB Corporate Research**

**MeRegio (e-Energy):**
- The detection of congestions
- Usage optimization of distribution grid
- Load and generation forecast

**AuRA-NMS (EPSRC):**
- Distributed intelligence in medium voltage substations
- Energy storage using Lithium-ion batteries (DynaPeaQ®)

**More MicroGrids (EC FP-6):**
- New protection algorithms and relay coordination for islanded mode
- Provision of frequency reserves from MicroGrids

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Source: ABB review 1/10 – Smart Teamwork

**address (EC FP-7):**
- The concept and information modeling for communication between different actors (IEC 61970)
- Network operation algorithms with active demand
Transmission Networks
EU Supergrid - Desertec

- A vision to help alleviate the world energy crisis
- Connect wind energy in the north and solar energy (CSP-Concentrated Solar Plant) in the south (MENA) for different load centers in central EU
- An “Electricity Highway” or “Supergrid” using a HVDC backbone is proposed

Source (both diagrams): Desertec Foundation
Clean Power from Deserts (WhiteBook)
Power and productivity for a better world™