Opportunities for Increasing Penetration Levels of Renewable Energy

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Overview:

- Renewable Energy Portfolio Standards
- Trends in Renewable Energy development
- Planning for Large-scale Renewable Power Integration
- Levelized Cost of Generation
- Hybrid Renewable Energy solutions
- Plug-in Hybrid Vehicles - Load Balancing
- Case studies with large scale integration
- Roles of Energy Storage
- Advanced Generator Power Electronics
- Summary
By 2025, we will need approx. 428 GW of new generation and capacity.
Wind Power Trends and Issues

Worldwide Capacity:
- 93.8 GW in 2007
- 19.7 GW added in 2007
- 5.2 GW added in US - 2007

Offshore: 1080 MW - 2007
- Short Transmission
- Land usage conflicts
- Improved production
- Less intermittency
- Improved capacity factors
- 40 GW proposed in Europe

Repowering:
- 2.2 to 4.3 increased production
- Reduction of number of wind turbines
- Increased capacity factor of 1.5 to 3.5
- Less visual impact
- Short permitting time

High Altitude Wind Power
Solar Market Growth $16 B in USA by 2015

Solar Growth Forecast 2005 – 2015 (MW)
Investments of $16 B by 2015 ($5.33/W)

Projected Hardware v/s EPC (100% = $16B)
- Solar-Thermal, 80%
- Photovoltaic, 20%
- EPC 40%
- Hardware & Equipment, 60%

Source: EIA - DOE
Levelized US Costs of Generation 2007

Cost of using latest technologies in the US
Taxes and Incentives Included

$ Cents/kWh

New Nuclear 12 10 13 10 32 79
Advanced CC Gas
IGCC Coal
Wind
Solar T
Solar PV

Need feed-in tariff structure (Europe) for USA to increase penetration
Planning Issues for Large-scale Renewable Power

- **Business-as-Usual with local < 20% penetration levels**
  - Increased effort in system planning – Intermittent nature.
  - Voltage support – Local and system-wide FACTS
  - Low-Voltage Ride-Through (LVRT) Requirements
  - Generator balancing and regulation.
  - Resource and load forecasting

- **Increased efforts for > 20% penetration levels**
  - Hybrid and matched hydro, solar, geothermal, wind generation, etc.
  - SmartGrids – Demand Response
  - Advanced renewable generator PE
  - Add energy storage – central and distributed
  - Asynchronous links – HVDC
  - Non-electric energy carriers – Hydrogen, etc.
Complementary Renewable Portfolio Mix

Temporal Pattern: July 2003 Average Day

Wind & Solar tend to be complementary.

Sources:- PG&E and CEC PIER
Plug-in Hybrid Cars (PHEV) – Load Balancing

- Several Manufacturers will start mass production in 2009
- Peak loading Dx issues – SmartGrid AMI
- Distributed Storage for Wind and Solar Power Balancing
- 600 GWh DESR potential from 10% of 200 million US passenger cars
- Linking different fuel options and energy transport mediums
Hybrid Energy Carrier Options

Hybrid AC/DC Networks

Peak Shaving

Fuel Cell

O₂ Gas

H₂ Gas

Hydrogen Storage

Local H₂ Use

H₂ Trucking

H₂ Pipeline

Electrolyzer
- Water purification
- Regulators
- Gas dryer
- Integrated Heating
- CHP

Local load

Water Supply

Power Electronics
- Grid Interconnection
- STATCOM / APF
- Max Power Tracker
- Electricity Storage
- Transfer Switch

Control, Protection Comms

Electrical Interconnection

Transport
Approach to Large Scale Renewables Integration

- Hybrid Energy Mix
- Advanced PE
- Fast Ramping
- Wide Operating Range
- Regulation capability

- Peak shaving
- Dispatch Renewables
- Mitigate Over Gen.
- Voltage Support & LVRT
- F-Regulation capability
- FACTS Integration
- Power Quality

- Price sensitive load
- Responsive to ISO
- Frequency Response
- Responsive to Wind
- SmartGrid / AMI
- Gen. - load match
- PHEV
Network Interconnection of 6 GW Offshore Wind

- 6 GW Wind by 2020 in 20 GW load (30%)
- Total cost 10 000€
- On-shore dynamic and static reactive power demand 2 - 6 GVAr
- Network upgrades - 650 M€
- 25-70 km offshore (AC or DC) Tx
- Bundling 150 kV AC offshore wind farm connections into 2 380 kV Offshore hubs
- 5th Harmonic resonance between cable capacitance and short-circuit reactance:
- Utilizing 2 HVDC links (BritNed & NorNed)
- Hybrid (AC + DC) off-shore network is preferred solution
- 2007 – 300 MW built out
Grid Inter-connection Alternatives

- 380 kV ring
- HVDC ring
Large-scale US Wind Impact Study

- Southern CA Renewable Energy Target
  - 2000 MW renewable energy portfolio,
  - 5,500 MW load demand in 2016 (36% penetration)

- Proposed hybrid approach to meet this requirement:
  - 1200 MW of wind generation
  - 900 MW of thermal solar generation

- Main findings and recommendations:
  - Need 500 kV SunLink transmission
  - Utilize hybrid wind - solar generation nature.
  - Power balancing with 1200 MW of wind and 900 MW of solar.
  - Voltage support with 300 MVAr MSC and 200 MVAr STATCOMs
  - Special protection schemes and curtailment.
  - Utilize pump-storage facilities
  - Study hybrid impacts of 4 GW – wind – solar- geothermal
Daily Normalized Wind, Solar and Load Patterns
Storage Characteristics and Technologies

Storage Power Requirements for Electric Power Utility Applications

Data from Sandia Report 2002-1314
The Netherlands Energy Storage Island

- Utilizing levy upgrades
- Low-head hydro
Thermal Solar with Molten Salt Energy Storage

Source:- 5 MW Sandia Lab. Storage Test Facility
Flywheel Plants for Regulation Services

Short-term (1 – 15 min) Supply and Demand Curve

Daily Supply and Demand Curve

Frequency Excursions with Spinning Reserve

Source: Beacon Power
Advanced Generator Power Electronics

- Variable Speed and Reactive Power control
- Dynamic Voltage Response Similar to STATCOM
- Advanced LVRT capability
- Spinning reserve emulation
- Active ancillary services – frequency regulation
- Energy storage integration
Summary:

- Most states have aggressive RPS > 10 - 25% by 2020
- Interconnection requirements are increasing
- Solutions to higher renewable penetration levels:
  - Hybrid wind, hydro, geothermal and solar generation mix
  - Energy storage
    - Short-term balancing, LVRT and Power Quality - 0.1 - 10 minutes
    - Regulation Services – 10 - 15 minutes
    - Medium-term peak shaving and load balancing 1 – 2 hours
    - Distributed Energy Storage – 600 GWh Plug-in-Hybrid potential
  - Advanced Generation Power Electronics
  - SmartGrid / AMI with Demand Response
Thank You !