NORWEGIAN ENERGY SOURCING STRATEGY

JWPA, Tokyo 27.10.2009

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THIS PRESENTATION

---> Statkraft today

---> Dynamic power system

---> Market mechanisms

---> Interplay between wind and hydro

---> Manual Imbalance Management

---> Imbalance Management through AGC

---> ”Swing producer”
STATKRAFT TODAY

- Main office
- Offices
- Hydro, gas, wind and district heating
- Baltic Cable
LEADING IN RENEWABLES

Generation of renewable energy in Europe (TWh)

- **2007**
  - Statkraft: 48
  - EdF: 50
  - Vattenfall: 38
  - Enel: 34
  - Iberdrola: 23
  - E.ON: 21
  - Fortum: 20
  - Electrabel (SUEZ): 19
  - EnBW: 12
  - Endesa: 11
  - SSE: 4
  - RWE: 4

- **2006**
  - Statkraft: 51
  - EdF: 49
  - Vattenfall: 33
  - Enel: 37
  - Iberdrola: 21
  - E.ON: 20
  - Fortum: 19
  - Electrabel (SUEZ): 19
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  - SSE: 4
  - RWE: 4

Source: Annual reports
HIGHLIGHTS WIND ACTIVITY 2008-2010

--- Norway
- Project pipeline of approx. 3000 MW

--- Sweden
- 1100 MW in late stage development

--- UK
- One onshore and one offshore wind farm in construction
- Two wind farms granted license
STATKRAFT’S NEXT PROJECTS

Blaengwen, Wales
10 turbines á 2.3 MW
In operation in 2010

Carraig Gheal, Scotland
Capacity of 40-50 MW
Final consent in June 2008
THE POWER SYSTEM IS DYNAMIC
VARIATION IN GENERATION
EXAMPLE: WIND FARM

Aktiv effekt (M W)

Smøla vindpark 40 MW, 66 kV
VARIATION IN GENERATION
EXAMPLE: HYDRO POWER PLANT (2 x 110 MW)
VARIATION IN WIND RESOURCE

--> Seconds - Minutes: Negligible affect on primary regulation
   - Studies show that wind power does not affect the short time balance
   - The variations are small and slow compared to fluctuations in load (consumption)

--> Hours: Affects the need for secondary/tertiary regulation
   - If the aggregated deviation from wind power and load is larger than that of the load alone

--> Abnormal weather conditions
24 HOURS A DAY AT THE CENTRAL DISPATCH

Change of Bid
Regulating Power Market

Change of Production Plans

Bid to Regulating Power Market

Final Production Plan

08.00 Change of shift
Night/Day

Preparation for short term optimization planning meeting

09.30 Opt. Planning meeting

Preparation of Bid sheets

12.00 Input to Nord Pool

Ca. 13.00 Prices and volumes from Nord Pool

Ca 1430 Preliminary production plan

19.30 Bid to Statnett

Bid to Regulating Power Market

19.00 Final Production Plan to Statnett

15.30 Change of shift
Day/Night
POWER RESERVE MARKET

--> Secondary (tertiary) reserve power

--> The TSO instructs a generator to refrain from bidding in the spot market. The system operator has the option to initiate the use of these units

--> Balancing Power Market (RKM)
   - Every day at 19:00 for the next 00-23 hours
   - The requirement is limited to 8% of the installed capacity
   - Totally 1600 MW in Norway

--> Balancing Power Option Market (RKOM)
   - During winter
   - 7 days ahead
### Market Data

#### Financial Markets
- Price formation [Nord Pool]
- Price formation [German]
- Price formation [Dutch]

#### Non-Exchange Trading
- Price formation [Dutch]

#### Power System Data
- Key figures
- Production
- Consumption
- Exchange
- Reserves
- Reg. power

#### Elcho
- Area prices
- Volumes
- Capacities
- Prices
- Market data

#### Key figures for Electricity Exchange Area

**Prices in EUR/MWh, Volumes in MW/h**

**27.11.09**

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Minimum: 30057, Maximum: 3139, Average: 30200.

**Statkraft**

side 13
HYDRO POWER IS A RELIABLE AND FAST RESERVE

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<th>Technology</th>
<th>Average regulation ability</th>
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<td>Oil/Gas</td>
<td>8-12, % of $P_N$ / minute</td>
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<td>Coal</td>
<td>4-8, ″</td>
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<td>Nuclear</td>
<td>5-10, ″</td>
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<td>Hydro</td>
<td>1.5-2.5, % of $P_N$ / second</td>
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**Start up time**
CCGT: 2-5 hours depending on technology
Hydro Power: 3-15 minutes depending on plant
HOW CAN HYDRO POWER CONTRIBUTE?

--> Deliver reserve services
   -- Keep rotating and fast reserves (short term)
   -- Storage of surplus energy in reservoirs (long term)

--> Refinement of new renewables
   -- Balancing wind, wave and tidal energy

--> Deliver peak effect and reduce need for spinning reserves from thermal power plants

--> Optimal for the economy and the environment
Net exchange for Norway

Week 43 (Volume in MWh/h, Import(+)Export(-))
Reservoir Content for Norway
Numbers in % of reservoir capacity
VARIATION IN LOAD AND ENERGY INFLOW OVER THE SEASONS

Week

Normalized data (%)

1 7 13 19 25 31 37 43 49

Wind energy
Water inflow
Load
'LOOK TO NORWAY'

Norway has 50% of the reservoir capacity in Europe
IMBALANCE MANAGEMENT

--- Alternative 1:

- All imbalances are managed by the imbalance market/regulating market (organized by the TSO)
- Imbalances created by wind power go into this market, and regulations are done according to bids

--- Alternative 2:

- We are managing our imbalances ourselves
- Automatic Generation Control (AGC)
COPING WITH POWER VARIATIONS?

How to include forecasts and deviations?
BALANCE MANAGEMENT

Balancing:
Challenge: Keeping the deviation from planned production as low as possible
MGC - MANUAL GENERATION CONTROL

- Start/stop of units
- Economic Dispatch
- Set point setting (MW)
- Activating reg. power (tertiary reserves)

Process control and surveillance
AGC - AUTOMATIC GENERATION CONTROL

Unit Controls:
- Automatic start/stop
- "Locked' to schedule
- Flexibility in control
- Economic Control

Measurements
- power system
- generation

Generator

Turbine

Valves/Gates

Speed Governor

Speed

To selected units

Set point changer

AGC

Frequency

Generation deviations
AGC - AUTOMATIC GENERATION CONTROL

Input from SCADA → ACE calculation → PI-controller → Generation distribution → Unit Control SCADA

Diagram:
- $f$ → $f_0$ → $R$ → $ACE$ → $PI$ → $PF_1$ → $UC_1$
- $P_{NI}$ → $P_{DNI}$ → $P_{WI}$ → $P_{DWI}$ → $ACE$ → $PI$ → $PF_i$ → $UC_i$
- $PF_n$ → $UC_n$
EXAMPLE: DEVIATION MANAGEMENT WITHOUT WIND
EXAMPLE: DEVIATION MANAGEMENT WITH WIND
EXAMPLE GENERATION SCHEDULE

Graph showing time intervals from 1 to 23 with different power generation levels for Pwind, PH1, PH2, and Total.

- Pwind: Blue line
- PH1: Purple line
- PH2: Yellow line
- Total: Cyan line
TRANSMISSION LIMITED GENERATION

![Graph showing transmission limited generation with various curves representing different parameters such as Pwind, TotGen, TranM, NewTot, PH1new, and PH2new over time intervals.](image)
The wind farms of Western Denmark produced close to rated power.

Norway was importing approximately 1000MW over the Skagerrak HVDC link.

A strong storm hit Denmark, and the wind farms started to cut out.

The total wind production was reduced from about 2200MW to 100MW in about 9 hours.
Norway started to reduce imports and then finally changed the power flow direction to export.

Norwegian hydro power saved the system in Western Denmark.
MAKING THE BEST OF THE AVAILABLE RESOURCES