Off-River Pumped Hydro Energy Storage

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New generation capacity world wide 2014

GW

Fossil | nuclear | Hydro | wind | PV | Bio | CST | geothermal

80 | 0 | 30 | 50 | 40 | 5 | 0 | 0
Retirement of coal fired power plant
Electricity reliability for 50-100% renewable energy penetration

- Wide geographical dispersion
- Technical diversity
  - Wind, photovoltaics, hydro, solar thermal, biomass
- Shift loads from night to day
- Mass storage
  - Pumped hydro – 99% of all storage
  - Advanced batteries, flywheels, molten salt etc
Pumped hydro
1500 MW at Tumut 3
Energy Storage

Worldwide installed storage capacity for electrical energy

- Compressed Air Energy Storage: 440 MW
- Sodium-Sulfur Battery: 316 MW
- Lead-Acid Battery: ~35 MW
- Nickel-Cadmium Battery: 27 MW
- Flywheels: <25 MW
- Lithium-Ion Battery: ~20 MW
- Redox-Flow Battery: <3 MW

Over 99% of total storage capacity

Source: Fraunhofer Institute, EPRI
Off-river Pumped Hydro Energy Storage

- PHES is 99% of all energy storage (160 GW)
  - much cheaper than alternatives
- Most PHES is on-river – with limited further prospects
- Off-river, there are unlimited excellent sites
- Misconceptions:
  - “Pumped hydro storage is at a mature stage of development, but there are limited locations where these facilities can be built”
  - “… further deployment of pumped hydro is severely limited by geographical and environmental site requirements …”
  - “Australia is flat and arid and has little potential for more hydro”
- Storage of a few hours most important
  - Spinning reserve, constrained transmission lines, time-shifting wind and PV
  - Morning and evening demand peak, wind lulls and short term clouds
  - Outages
  - Time to bring up low duty cycle coal/gas/biomass plant
Off-river PHES

- A pair of “turkey nest” “farm dams”
- Small reservoirs (hectares); large power (100 MW)
- Hundreds of good sites
  - Reservoir on top of a hill ➔ large head (300-900m)
  - Avoid flood control costs
- Example
  - Twin 5 Ha reservoirs
  - 15m deep, 600m head ➔ 200MW for 5 hours

Bundeela Pondage (Shoalhaven PHES system) is artificial
Lake Burrendong wind farm – 320m head
Water and environment

• Environment
  – Exclude national parks and sensitive areas
  – Hectare-scale reservoirs, small footprint

• Water
  – Water recycled, supplemented with local runoff
  – 1000 MWh PHES system near Whyalla in SA
    • Water requirement = 0.03% of SA Water sales
    • 25 times smaller than a coal power plant per GWh
Off-river Hydro Storage

- Spinning reserve for SA
- More wind utilisation in WA
- Better price for load-following output rather than wind/sun following
- Avoid duplication of a powerline by trimming sun/wind peaks
- Reduce transformer & powerline size/cost by sending half the power to storage and only half to load in real time
- PV/wind/storage precincts
- Arbitrage between on/off peak
  - buy low, sell high
- Facilitate 50-90% PV/wind penetration

Excess energy sent to the store
Additional cost: < 1-2 c/kWh
Drawing energy from storage
Example cost calculation

Generator/pump capacity: 200 MW
Head: 600 m
Round trip storage efficiency: 80%
Reservoirs: two, each 5 Hectares, 15m deep (200 MW for 5 hours)
Pipe length: 3km; Transmission line length: 5km; New road construction: 5km
Empty/fill cycles per day: 2
Nominal discount rate: 10% (inflation rate: 2.5%)
System lifetime: 50 years; O&M: 1% per year of the capital cost
System cost: $1100/kW

⇒ Storage cost: $33 per MWh (for energy that is actually stored)
⇒ Far cheaper than batteries
South Australia - spinning reserve

Hills east of Whyalla with up to 600m head (vertical scale exaggerated)
Snowtown windfarm (370 MW, South Australia)

Notional 5km long pipe; altitude difference 300m; twin 3 Hectare dams; 3 hours @ 200 MW
Sapphire Wind project – 300m head
PHES in WA - Facilitating wind and PV

Key
- Green triangle: Identified prospective PHES sites (Heads > 200m)
- Red: PHES areas with 100-150m head
- Yellow: PHES areas with 50-100m head
- Blue: PHES areas with < 50m head

Notes
1. A dozen of prospective PHES sites (Heads > 200m) with total energy potential 9.72 GWh have been identified in the southwest WA.
2. See "A brief summary of prospective STORES sites in Western Australia (Head > 200m)" for more information.

Opportunities for Short-Term Off-River Pumped Hydro Energy Storage (STORES) in the Southwest WA
What we are doing

• Find all of the good PHES sites: a PHES Atlas
  – Exclude national parks and sensitive areas
  – Add in solar data, wind data, transmission lines

• Find PV/wind precincts
  – PHES + transmission line + good wind and sun

• Detailed market and financial analysis
  – A reliable costing tool

• Initial results
  – 100% renewable energy needs 20GW PHES
  – Adds 10-15% to total cost