EPOC Winter Workshop
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Can virtual disaggregation integrate large-scale storage into the NZEM?

Caveat:
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This talk just considers one question…

(How) could a large scale "storage" development be integrated into the NZEM, without unduly:

- Crowding out "better" smaller scale options,
- Disrupting the competitive balance, or
- Concentrating decision-making responsibility in one party/model?

This talk is not about:

- Small/medium scale distributed storage options
- The need for, or value of, large scale storage
- The design, management, or economics of particular large scale options
- Potential political or commercial negotiations for implementation

First, stand-alone “battery equivalent” storage

What is "battery equivalent" storage?

Completely closed systems:

- Absorb (low valued) electrical energy
- Store its potential energy in an internally re-cycled "storage medium"
- Release (high valued) electrical energy
- With some losses at each step
  - E.g. battery, flywheel, closed loop pumped hydro

Completely open systems:

- Absorb (low valued) electrical energy
- Store its potential energy in a freely available "storage medium"
- Release (high valued) electrical energy, and the storage medium
- With some losses at each step
  - E.g. compressed air, open-loop pumped hydro, non-traded hydrogen

How would "virtual disaggregation" apply?

History

"Virtual Disaggregation" has been proposed or implemented elsewhere:

- SEE Barroso et al CIGRE 2012

The two most relevant examples there are:

- Section IIC on the Columbia river regime
- Section IIIB on the Hunt/Read Tasmanian proposal

We discuss generalisations of the Tasmanian regime, recently considered by MBIE for application to large-scale pumped storage or alternatives in NZ

- The basic concept is a "natural form" financial contract
- Approximating the physical characteristics of the underlying supply
- Just like "call options" approximate thermal station capabilities

(The financial water storge/transportation rights discussed by Mahakalanda et al (2014/15) have some affinities, but are not really suitable in this context.)

L.A. Barroso, S. Granville, P.R. Jackson, M.V. Pereira & E.G. Read "Overview of Virtual Models for Reservoir Management in Competitive Markets" *Proceedings 4th IEEE/Cigré International Workshop on Hydro Scheduling in Competitive Markets*. Bergen, Norway, 2012.

Mahakalanda, E.G.Read, S.R. Starkey & S. Dye "Financial Hedging Instruments for Water Markets" *ORSNZ*, 2014

`I. Mahakalanda, E.G. Read & S. Dye "Financial Rights and Obligations for Water Delivery in Mixed Use Catchments" *ORSNZ*, 2015

How would "virtual disaggregation" apply?

Setup (for open/closed system, with no "natural inflows")

Participant *n* holds contract specifying:

EFF, WASTE, $CHARGEMAX_n$ $STORMAX_n$ $GENMAX_n$ in energy terms

- **EFF** (=0.8, say) accounts for roundtrip charging/generation inefficiencies at the charging stage
- **WASTE** (=0.01 say) accounts for per period wastage in storage

Rolling energy account balance for participant *n*:

$$stor_n^{t+1} = (1\text{-}WASTE) * stor_n^t + EFF \text{ x } charge_n^t - gen_n^t$$

With:

$$0 \leq charge_n^t \leq CHARGEMAX_n$$

$$0 \leq stor_n^t \leq STORMAX_n$$

$$0 \leq gen_n^t \leq GENMAX_n$$

How would "virtual disaggregation" apply?
Operations

Right holders could specify:

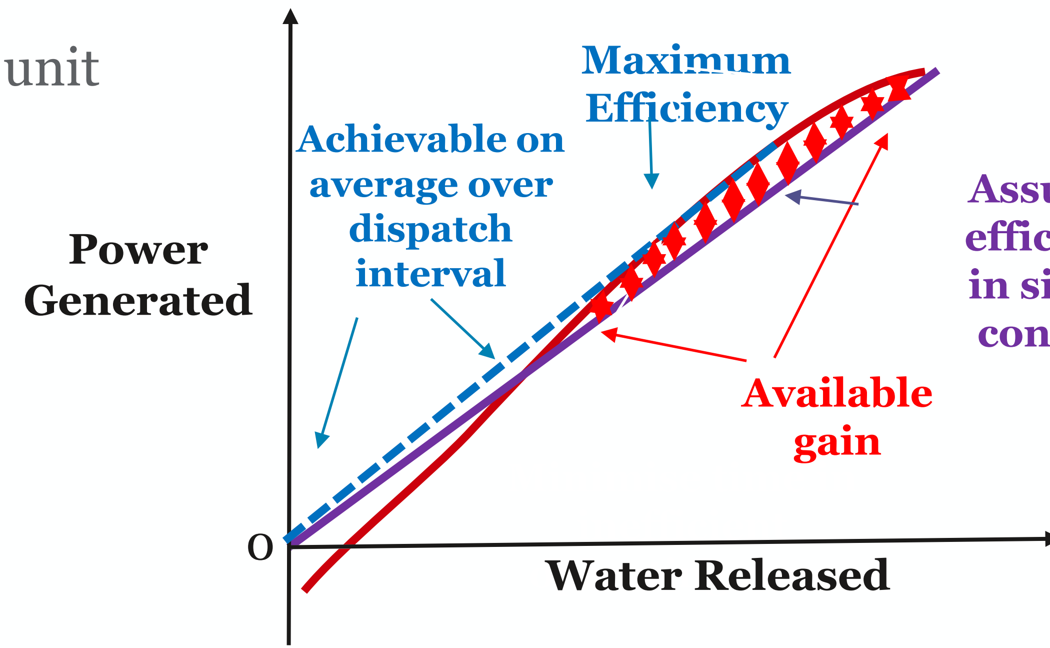
- Desired physical dispatch schedules (as in Columbia River implementation)
- Quantity calls on financial options (as proposed for Tasmania)
- Desired offer schedules (as suggested here)

The facility operator:

- Aggregates and rationalises requested offers
- Makes physically reasonable offer to NZEM
- Operates like any other facility under NZEM rules
- Pays, or is paid, under NZEM settlement rules
- Settles with participants according to their requested offers and virtual model
- And so has incentives to match aggregate contract calls

Conservative virtual models
let operators make modest profits

E.g. for a single hydro unit



Participants optimise operation of virtual facilities just like physical facilities .... but with far less hassle

Neither operator nor participant has "market power"

How would "virtual disaggregation" apply?

Simplification?

"Tank options" specify only Storage/Generation capacity

But these tanks must be filled by purchase of stored energy from:

- A (regulated?) single seller for the facility?
- A (competitive?) market supplied by other participants?

So a tank option holder has:

$$stor_n^{t+1} = (1\text{-}WASTE)^* \, stor_n^{t} + buy_n^{t} - sell_n^{t} - gen_n^{t}$$

Both option types can co-exist, so general storage balance equation is:

$$stor_n^{t+1} = flow_n^{t} + (1\text{-}WASTE)^* \, stor_n^{t} + buy_n^{t} - sell_n^{t} + EFF \times charge_n^{t} - gen_n^{t}$$

Where $flow_n^t$ is n's share of any natural inflow, proportional to storage capacity

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What could “virtual disaggregation” deliver?

Control of market power, particularly wrt “storage capacity”:

- Traditionally provided by hydro and thermal fuel stock/trading
- Now identified as critical resource sustaining renewable future
- To be supplied by:
  - Conventional/pumped hydro
  - Alternatives such as biomass, biofuel, or H2/NH3
  - Batteries
  - Short/long-term DSM

Integrating such options into market arrangements

Market valuation of “non-commercial” developments

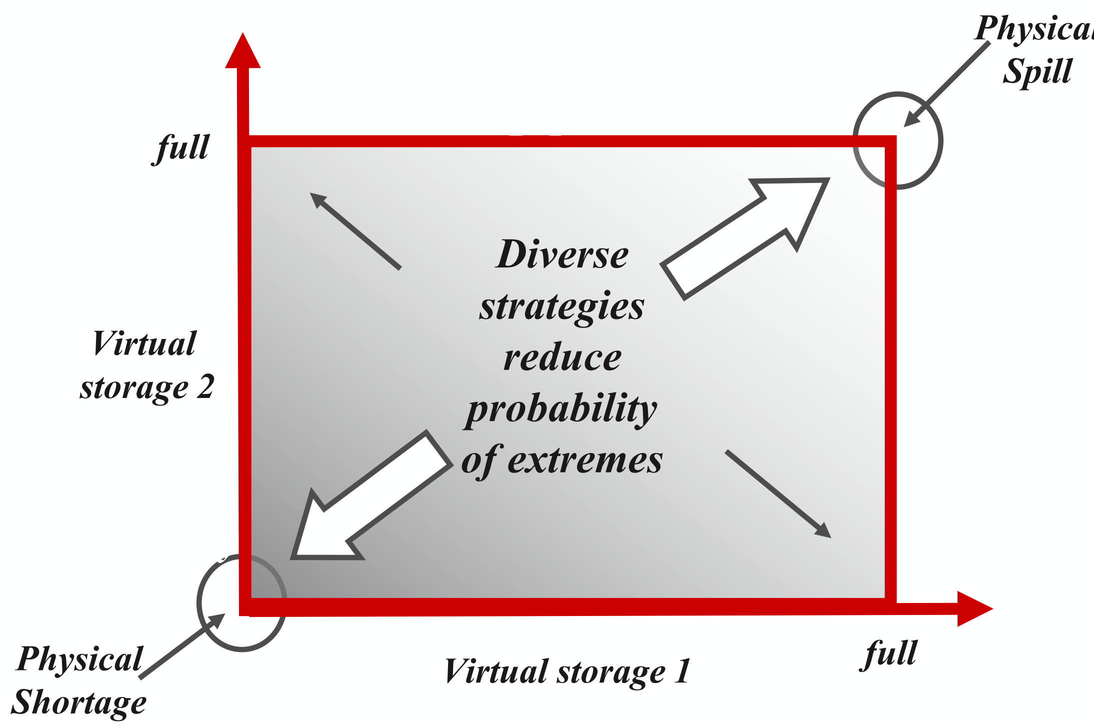
Possibly competitive markets for “storage capacity” across technologies

“Evening up” competitive balance

Diversifying management of large-scale developments

Why might diversified management be preferred?

(Apart from market power issues)



But what about "embedded" supply/demand-side storage?

“Supply-side” storage supports controllable generation

”Generation is from a “storage medium” that is in limited supply and/or valued by others, typically for other uses, and:

- Is bought/collected and stored (in a possibly modified form) with or without significant input of (low valued) electrical energy
- Released in a possibly (further) modified form that may have positive/negative “downstream” value
- While producing (high valued) electrical energy
- With some losses at each step
- E.g. Conventional hydro, conventional thermal, hydrogen /biofueled thermal

“Fuel” may be an elastic concept

“Internationally traded fuels” provide almost unlimited <u>effective</u> storage:

- In the “upstream” (national/international) supply pipeline
- With geothermal similarly “unlimited”

But absence of limits means that conventional call-option contracts work

- “Storage” situations arise from <u>limits</u> on timing or delivery rate

“Non-traded fuels” (eg host system water) have more limited supply:

- But high opportunity cost for the host system
- And those opportunity costs can apply on entry and/or exit from storage
- With wastage/transformation to be accounted for
- In addition to the cost/value of electricity consumed/generated

And the same applies to unconventional fuels (biomass/hydrogen)

“Demand-side” storage supports controllable consumption

The “storage medium” is the product of, and/or input to, some electricity-consuming process, which:

- Is normally produced with significant electrical energy input, and stored
- Released to maintain positive “downstream” value while production is reduced
- Thus reducing demand for (high valued) electrical energy
- With some losses at each step
- E.g. Thermal inertia, export aluminium/hydrogen

Exported products can also have virtually unlimited “storage”

- In the “downstream” (national/international) distribution pipeline
- But limits on delivery rates or timing create “storage” issues

And deferrable electricity consumption could relate to processes rather than products: (like dish-washing, or leisure activities)

In principle

E.g. in a system specifically developed to provide storage:

Supply/demand side options are not very different, mathematically:

- Although particular proposals differ greatly in complexity

We could extend "virtual disaggregation" throughout the upstream/downstream "host system":

- As implemented in the Columbia catchment, and proposed in Tasmania
- So every "right holder" optimises/calls a proportional "system slice"

Or we could "deconstruct" rights, by system component, and

- Let participants form/manage their own (complementary) virtual systems
- With some restrictions on bottleneck resource holdings

In practice:

Supply/demand networks can be complex and non-transparent

Incumbent host system managers would be understandably wary about applying "virtual disaggregation" to existing systems

The management expertise of electricity market participants:

- May not extend to (virtual) complex hydro generation systems;
- Probably does not extend to (virtual) fuel supply systems; and
- Definitely does not extend to (virtual) non-energy supply/demand systems

Some form of simplified "tank option" seems more plausible:

- Implying a need to create competition, or control monopoly
- For control of energy supplied to the "tank"
- And/or for supply/disposal of the "storage medium"
- At some interface node(s)

The End