Closing the gap between fixed and dynamic Flow Battery models for schedule optimisation.

4th September 2019

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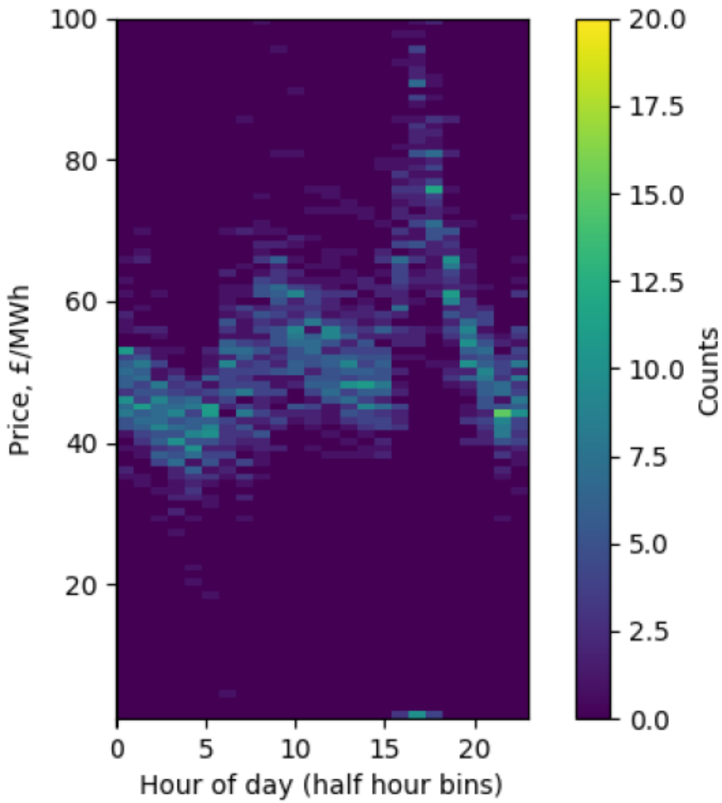
Schedule Optimisation for BESS

Optimisation of battery scheduling is crucial for revenue.

Algebraic modelling commonly used for both stochastic and deterministic problems.



Linear Programming (LP) Approach

LP is the simplest form of algebraic model for BESS

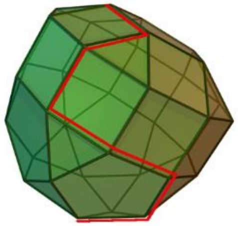
$$Objective = maximise(\tau \sum_t price_t(\boldsymbol{P_t^D} - \boldsymbol{P_t^C}))$$

$$subject\ to: \quad SOC_{min} \le SOC_t \le SOC_{max}$$

$$where: \quad SOC_t = SOC_{t-1} + \frac{\tau}{E_{BESS}} \left(\boldsymbol{P_t^C}\sqrt{\eta} - \frac{\boldsymbol{P_t^D}}{\sqrt{\eta}}\right)$$

Commonly used in academic TEA for BESS

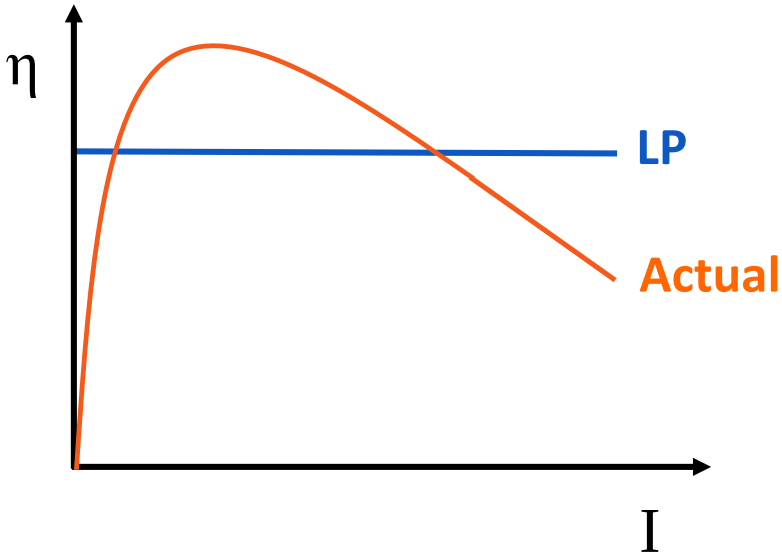
Solution is found very quickly.



LP Approach: drawbacks

ESS model is fixed state, so dynamics are not captured.

For example, round trip efficiency for a flow battery:



Making η a function of P makes problem non-convex.

Our quadratic (QP) approach

Key: separate coulombic and voltaic components.

$$Obj. = max.\left(A\tau \sum_t price_t\left(\boldsymbol{I_t^D}\left(OCV_{SOC_{50\%}} - V_{Far.}\right) - \boldsymbol{I_t^C}\left(OCV_{SOC_{50\%}} + V_{Far.}\right) - \left(\boldsymbol{I_t^C}^2 + \boldsymbol{I_t^D}^2\right)ASR\right)\right)$$

$$subject\ to: \quad SOC_{min} \leq SOC_t \leq SOC_{max}$$

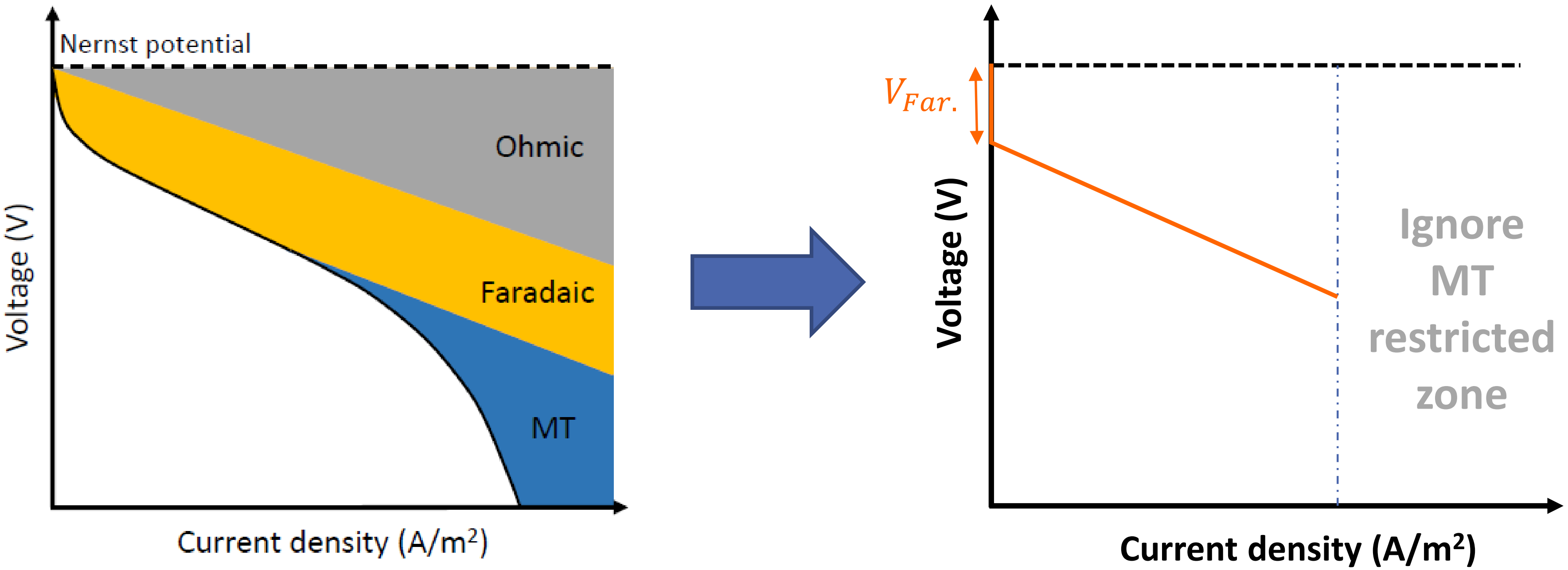
$$where: \; SOC_t = SOC_{t-1} + \frac{A.\tau}{C_{BESS}}\left(\boldsymbol{I_t^C}\sqrt{\eta_{Coul.}} - \frac{\boldsymbol{I_t^D}}{\sqrt{\eta_{Coul.}}}\right)$$

Voltaic losses can be expressed as function of *I* without losing convexity.

Coulombic losses still modelled as constant fraction…

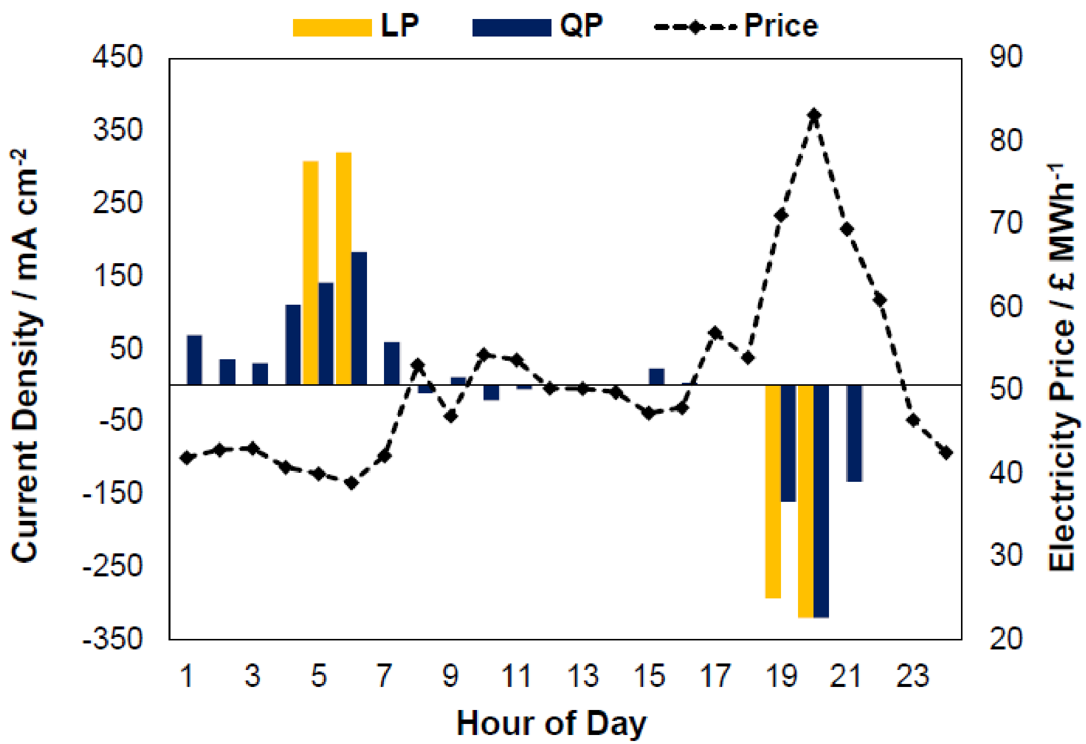
Our quadratic (QP) approach

Necessary approximation of polarization curve for voltaic losses:



Case study: VRFB for energy mgmt.

Case study: 4h VRFB* performing day-ahead energy management.



With QP we can access extra revenue.

~19 % more for N2EX day-ahead arb. across 2017

* Parametrised from *David Reed et al. J. Electrochem. Soc. 2016, 163, A5211-A5219*
4 h duration at rated power (that which gives 75% round-trip DC efficiency – max power is greater).

Wrap up

We’ve introduced a simple formulation that unlocks extra arbitrage revenue.

Principles apply to all electrochemical ESS

Further improvements made (not enough time here!)

Work currently under peer review.

Next steps:

Apply model to behind meter app. – ancillary services + peak shaving.

Collaborate on model validation and alternative chemistries.

Thanks for listening!

The author gratefully acknowledges support from the EPSRC via grant EP/L016818/1 which funds the Centre for Doctoral Training in Energy Storage and its Applications, and from Drax Group.

And thanks to Sol Brown: