Limitations of the HPPC method

- This enhanced version of the HPPC method is still limited:
  - The cell model used is too primitive to give precise results
    - Overly optimistic or pessimistic values could be generated, either posing a safety or battery-health hazard or being inefficient in battery use
  - Further, HPPC assumes initial equilibrium condition, not true in general
- Hence, we usually de-rate the HPPC estimates by some "trust factor"
- A better cell model, combined with a maximum-power algorithm that uses the cell model, can give better power prediction

Assumptions on new method

- Now assume more accurate model in state-space form

$$x_n[k+1] = f\big(x_n[k], u_n[k]\big)$$
$$v_n[k] = h\big(x_n[k], u_n[k]\big)$$

- Also assume ΔT seconds is exactly $k_{\Delta T}$ sample intervals
- Then, can use model to predict voltage ΔT seconds into future by

$$v_n[k+k_{\Delta T}] = h\big(x_n[k+k_{\Delta T}], u_n[k+k_{\Delta T}]\big),$$

  where $x_n[k+k_{\Delta T}]$ found by simulating state equation for $k_{\Delta T}$ time samples
- Assume that cell input remains constant from time index k to $k+k_{\Delta T}$, and denote it simply as u_n

Searching for limiting current

- Method then uses a bisection search algorithm (next lesson) find $i_{\max,n}^{\text{dis,volt}} = i_n$ by looking for i_n (as member of u_n) so

$$v_{\min} = h\big(x_n[k+k_{\Delta T}], u_n\big), \quad \text{or}$$
$$0 = h\big(x_n[k+k_{\Delta T}], u_n\big) - v_{\min}$$

- Also look for $i_{\min,n}^{\text{chg,volt}} = i_n$ by looking for i_n that causes equality in

$$v_{\max} = h\big(x_n[k+k_{\Delta T}], u_n\big), \quad \text{or}$$
$$0 = h\big(x_n[k+k_{\Delta T}], u_n\big) - v_{\max}$$

- Once again, SOC-based current limits $i_{\max,k}^{\text{dis,soc}}$ and $i_{\min,k}^{\text{chg,soc}}$ are computed as before

Special case

- A special case is when the state equation is linear—when
$$x_n[k+1] = Ax_n[k] + Bu_n[k],$$
where A and B are constant matrices
- Then, for input u_n constant over the entire prediction horizon, we have
$$x_n[k+k_{\Delta T}] = A^{k_{\Delta T}} x_n[k] + \left(\sum_{j=0}^{k_{\Delta T}-1} A^{k_{\Delta T}-1-j} B \right) u_n$$
- Most of these terms may be pre-computed without knowledge of u_n in order to speed calculation using the bisection algorithm

Power limits

- Charge power is then computed as
$$P_{\min}^{\text{chg}} = N_p \sum_{n=1}^{N_s} i_{\min}^{\text{chg}} v_n(t+\Delta T) = N_p \sum_{n=1}^{N_s} i_{\min}^{\text{chg}} h(x_n[k+k_{\Delta T}], u_n),$$
with u_n containing $i_{\min}^{\text{chg}}$ as its value for current
- Discharge power is computed as
$$P_{\max}^{\text{dis}} = N_p \sum_{n=1}^{N_s} i_{\max}^{\text{dis}} v_n(t+\Delta T) = N_p \sum_{n=1}^{N_s} i_{\max}^{\text{dis}} h(x_n[k+k_{\Delta T}], u_n),$$
with u_n containing $i_{\max}^{\text{dis}}$ as its value for current.

Summary

- Desire to improve upon HPPC method by using full cell model, initialized with full state estimate at present time
- You have learned the principle of how we can do this, by searching for value of dis/charge current that causes future model state and output to reach limits
- All that remains is to see how to determine u_n to meet the cell voltage limits
  - We look at this in the next topic