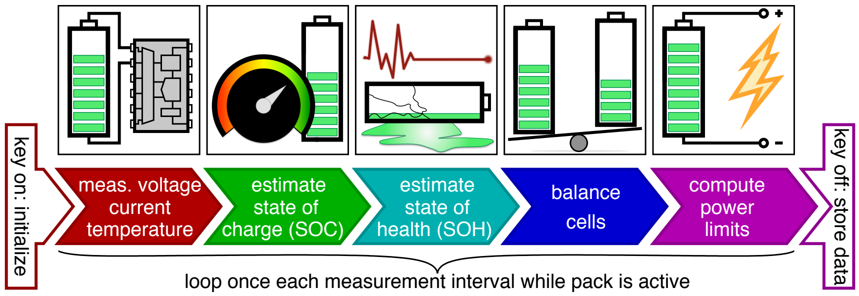
Final major BMS estimation task

- We have now seen various methods to perform state and health estimation for battery cells and packs
- Knowing state and parameters, learned how to estimate available cell, pack energy
- Final major variables that we must estimate are cell and pack power limits

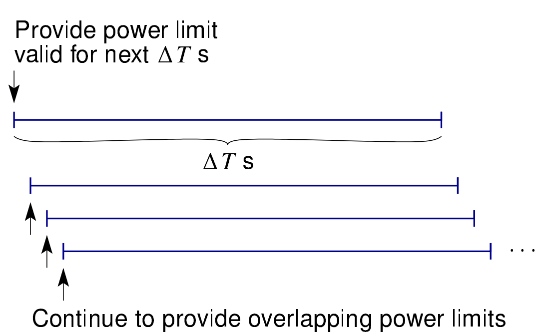


Problem concept

- Power limit specifies how quickly we may add or remove energy from pack without violating a set of design constraints
- We assume that principal design constraints are on cell terminal voltage (common practice today)
- Real issue, however, is not cell voltage, but incremental damage that is experienced by the cell if it is operated at high rates
- A current research topic searches to use physics-based models and power-limits calculations to compute limits based on incremental damage rather than on terminal voltage

Moving-horizon power limits

- The power-limit calculations must be predictive:
  - Must specify limits on constant dis/charge power that are guaranteed to be "safe" over some future time horizon of ΔT s



Problem definition

- Specifically, we want to address one of the following three problems:
  1. Discharge power: Based on present battery-pack state, estimate maximum discharge power that may be maintained constant for ΔT s without violating pre-set design limits on cell voltage, SOC, maximum design power, or current
  2. Charge power: Based on present battery-pack state, estimate maximum charge power that may be maintained constant for ΔT s without violating pre-set design limits on cell voltage, SOC, maximum design power or current
  3. Both discharge and charge power: Any combination of (1) and (2), where ΔT may have different values for charge and discharge

Some notation we will use

- The notation and assumptions we employ are as follows:
  - We denote the number of cells in the battery pack by N
  - Cell voltage for cell number n in the pack by $v_n(t)$; where design limits $v_{\min} \leq v_n(t) \leq v_{\max}$ must be enforced for all cells
  - State-of-charge by $z_n(t)$; where we enforce $z_{\min} \leq z_n(t) \leq z_{\max}$
  - Cell power by $p_n(t)$; where we enforce $p_{\min} \leq p_n(t) \leq p_{\max}$; and
  - Cell current by $i_n(t)$; where we enforce $i_{\min} \leq i_n(t) \leq i_{\max}$
- Any particular limit ($v_{\max}$, $v_{\min}$, $z_{\max}$, $z_{\min}$, $i_{\max}$, $i_{\min}$, $p_{\max}$, $p_{\min}$) may be removed if desired by replacing its value by $\pm\infty$, as appropriate

Some conventions we will use

- Any limit may also be a function of temperature and other factors pertaining to present battery pack operating condition
- Different cells may have different limits should it be desirable
- Here, we assume that discharge current and power have positive sign and charge current and power have negative sign
  - Other conventions are accommodated by minor math changes
- The battery pack is assumed to comprise N_s cell modules connected in series, where each cell module comprises N_p individual cells connected in parallel, with $N_s \geq 1$, $N_p \geq 1$, and $N = N_s N_p$

Summary

- Final major topic of this specialization is on estimating cell and pack power limits
- How quickly may we add/remove energy without violating design limits?
- Estimate of power limits must be predictive over time horizon ΔT s
- Problem is to estimate discharge and/or charge power limits
- Notation and conventions have been defined
- We are now ready to study some methods