Power-limits estimation example

- In this lesson, we look at Octave code to compute HPPC limits
- Code starts by loading data, configuring parameters

```
% Parameters
load('CellModel.mat');                 % ESC cell model
load('CellData.mat');                  % time/current/voltage/soc/spkfSOC/bounds

% Cell Configuration
T       = 25;                                    % [degC] ambient temperature
Thorz   = 10;                                    % [s] horizon time
z       = 0.5;                                   % [] initial cell SOC
Ns      = 1;                                     % [] number of series cells
Np      = 1;                                     % [] number of parallel cells

% Operational Limits
zmin = 0.1;     zmax = 0.9;                      % [] soc limits
vmin = 2.8;     vmax = 4.3;                      % [V] voltage limits
imin = -200;    imax = 350;                      % [A] current limits
pmin = -inf;    pmax = inf;                      % [W] power limits
```


Find ΔT resistances

- Next, find effective dis/charge resistances over horizon ΔT
- Use 10C pulses to do so

```
% Effective Resistances
Q    = getParamESC('QParam',T,model);
iChg = 10*Q*[zeros(5,1); -ones(Thorz,1); zeros(5,1)];  % [A] charge pulse
iDis = 10*Q*[zeros(5,1);  ones(Thorz,1); zeros(5,1)];  % [A] discharge pulse
[vk,~,~,~,~] = simCell(iChg,T,model,1,z,0,0); % 1 = sample period
dvChg  = max(vk)-vk(1);
iChg   = min(iChg);
RChg   = abs(dvChg/iChg);
fprintf('Rchg = %2.4f (mOhm)\n',1000*RChg);

[vk,~,~,~,~] = simCell(iDis,T,model,1,z,0,0); % 1 = sample period
dvDis  = min(vk)-vk(1);
iDis   = max(iDis);
RDis   = abs(dvDis/iDis);
fprintf('Rdis = %2.4f (mOhm)\n',1000*RDis);
```


HPPC truth power limits

- We now compute “truth” power limits using exact SOC from carefully calibrated lab tests

```
% HPPC Power Estimation: Truth
OCV       = OCVfromSOCtemp(soc,T,model);
iDisMaxV = (OCV-vmin)/RDis;
iDisMaxZ = (soc - zmin)*3600*Q/Thorz;
iDisMax   = max(0,min([iDisMaxV;iDisMaxZ;imax*ones(size(soc))]));
pDisMax   = min(vmin*iDisMax,pmax*ones(size(soc)));
iChgMinV = (OCV-vmax)/RChg;
iChgMinZ = (soc - zmax)*3600*Q/Thorz;
iChgMin   = max([iChgMinV;iChgMinZ;imin*ones(size(soc))]);
pChgMin   = min(0,max(vmax*iChgMin,pmin*ones(size(soc))));
HPPC.pDisMax = pDisMax;
HPPC.pChgMin = pChgMin;
```

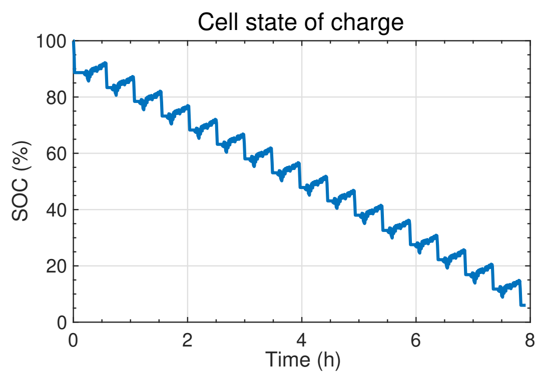
HPPC SPKF power limits

- We now compute more realistic power limits using SOC estimate and bounds produced by SPKF

```
% HPPC Power Estimation: SPKF
OCVDis    = OCVfromSOCtemp(spkfSOC-bounds,T,model);
OCVChg    = OCVfromSOCtemp(spkfSOC+bounds,T,model);
iDisMaxV = (OCVDis-vmin)/RDis;
iDisMaxZ = (spkfSOC-bounds - zmin)*3600*Q/Thorz;
iDisMax   = max(0,min([iDisMaxV;iDisMaxZ;imax*ones(size(soc))]));
pDisMax   = min(vmin*iDisMax,pmax*ones(size(soc)));
iChgMinV = (OCVChg-vmax)/RChg;
iChgMinZ = (spkfSOC+bounds - zmax)*3600*Q/Thorz;
iChgMin   = max([iChgMinV;iChgMinZ;imin*ones(size(soc))]);
pChgMin   = min(0,max(vmax*iChgMin,pmin*ones(size(soc))));
spkfHPPC.pDisMax = pDisMax;
spkfHPPC.pChgMin = pChgMin;
```


Example experiment

- We execute the code to view representative results
- A cell is subjected to a sequence of sixteen UDDS cycles, separated by discharge pulses and five-minute rests
- SOC increases by about 5 $\%$ during each UDDS cycle, but is brought down about 10 $\%$ during each discharge between cycles
- The entire normal operating range for this cell (10 $\%$ to 90 $\%$ SOC) is excited during the cell test



Parameters for test

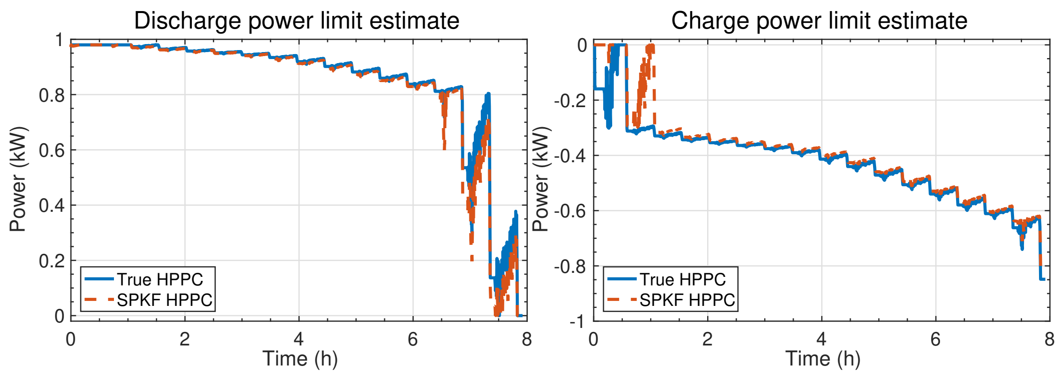
- Experiment computes power for single cell, $N_s = 1$ and $N_p = 1$
- Cell has nominal capacity of 7.5 Ah, and $\Delta T = 10$ s for both charge and discharge
- Operational limits for the power calculations are listed
- Pulse resistances are found to be

$$R_{\text{dis},\Delta T} = 3.539\,\text{m}\Omega$$
$$R_{\text{chg},\Delta T} = 3.517\,\text{m}\Omega$$

Parameter	Minimum	Maximum
$v_n(t)$	2.8 V	4.3 V
$i_n(t)$	−200 A	350 A
$z_n(t)$	0.1	0.9
$p_n(t)$	$-\infty$	∞

Results from running code

- Dis/charge power limits are plotted below
- SPKF method more conservative because uses bounds



Summary

- You have now learned how to write Octave code to compute HPPC power limits
- Code includes limits on future voltage, future SOC, current magnitude and power magnitude
- Example showed that limits are enforced on current, future SOC, and future voltage for a representative case
- SOC estimate plus bound produced by SPKF agree well with truth calculations, and produce slightly conservative estimates (good!)