Review of key concept from prior lesson

- In the previous lesson, you learned how to use the ESC model to simulate a constant-voltage profile
- Critical observation: cell voltage comprises "fixed" part (doesn't depend on present cell current) and "variable" part $-R_0 i[k]$ (does depend on present cell current)

$$
\begin{aligned}
x[k] &= A[k-1]x[k-1] + B[k-1]i[k-1] \\
v[k] &= \underbrace{\text{OCV}(x[k]) + \text{hysteresis}(x[k]) - \text{diffusion}(x[k])}_{\text{not a function of instantaneous current}} - R_0 i[k]
\end{aligned}
$$

- If fixed part is $v_f[k]$, we have $v[k] = v_f[k] - R_0 i[k]$
- This allowed us to solve for $i[k]$ to achieve a desired $v[k]$

Computing $i[k]$ to meet power demand

- We can use the same observation to simulate constant power
- Power equals voltage times current

$$
\begin{aligned}
p[k] &= v[k]i[k] = (v_f[k] - R_0 i[k])i[k] \\
0 &= R_0 i^2[k] - v_f[k]i[k] + p[k]
\end{aligned}
$$

- This quadratic in $i[k]$ can be solved to determine cell current to meet power demand

$$
i[k] = \frac{v_f[k] - \sqrt{v_f^2[k] - 4R_0 p[k]}}{2R_0}
$$

- Note: Sign of radical must be negative for positive overall cell voltage

Simulation setup

- Can simulate constant power quite easily now
- Consider comparing CC/CV to CP/CV charging
- Can use `hold on` for previous graphs, then simulate a CP/CV scenario, then overlay new CP/CV results on top of prior CC/CV results
- Will show setup and main code, but omit the plotting code
- Setup code resets initial state $x[0]$ of model, sets desired power level

```
% Now, simulate CP/CV
z  = 0.5; irc = 0; h  = -1; s = -1 % initialize to 50% SOC, resting
CP = 35; % constant power limit of 35 W in CP/CV charge
```

Main Octave simulation code

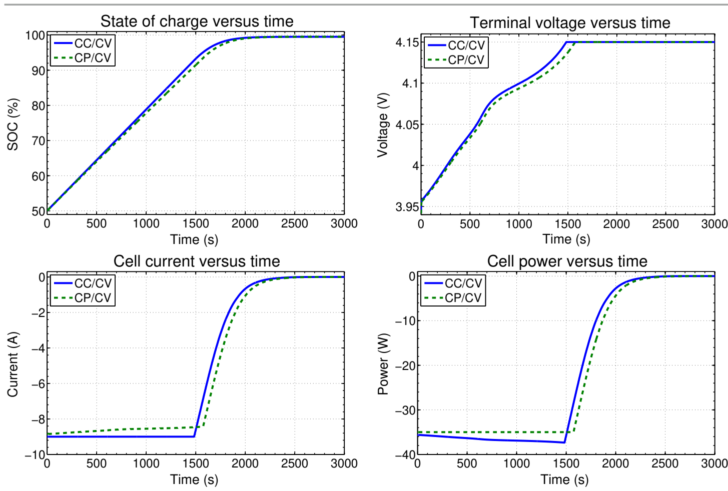
- This is the code that simulates CP/CV itself

```
for k = 1:maxtime,
  v = OCVfromSOCtemp(z,T,model) + m*h + m0*s - r*irc; % fixed voltage

  % try CP first, but if voltage too high switch to CV instead
  ik = (v - sqrt(v^2 - 4*r0*(-CP)))/(2*r0);
  if v - ik*r0 > maxV, ik = (v - maxV)/r0; end

  z = z - (1/3600)*ik/q;              % Update cell SOC
  irc = rc*irc + (1-rc)*ik;           % Update resistor currents
  fac = exp(-abs(g.*ik)./(3600*q));
  h = fac.*h + (fac-1).*sign(ik);     % Update hysteresis voltages
  if abs(ik)>1e-3, s = sign(ik); end  % Update current sign
  storez(k) = z;                      % Store SOC for later plotting
  storev(k) = v - ik*r0;
  storei(k) = ik;                     % Store current for later plotting
  storep(k) = ik*storev(k);
end % for k
```


Simulation results



- Simulation results when charging a battery cell from 50 % SOC to max voltage using CC/CV and CP/CV profiles

Summary

- In this lesson, you learned a second application of the observation that cell voltage can be broken into a fixed part and an instantaneous part
- You have now learned how to simulate a constant-power profile for a battery cell
- You saw how to implement this in Octave/MATLAB code and saw an example comparing CC/CV to CP/CV charging of a battery cell
- Now, we will turn our attention to using the same observation to enable simulation of battery packs