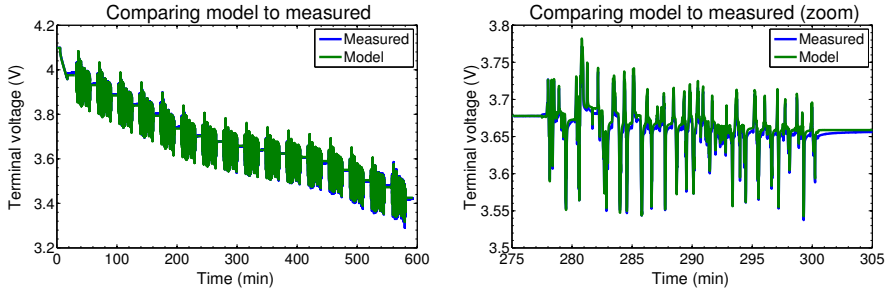
Prediction of voltage

- To give a better feel for what to expect for parameter values of an ESC model and its predictive capabilities, we present some modeling results in this lesson
- For the first results, data were collected from a 25 Ah automotive battery cell using the procedures outlined in this course, and OCV and dynamic parameters were estimated from the data (using one R–C sub-circuit in the model)
- First, we concentrate on simulating the optimized model open-loop, and comparing its predictions against the measured voltage data for a test conducted at 25 °C.

Example results: Voltage prediction

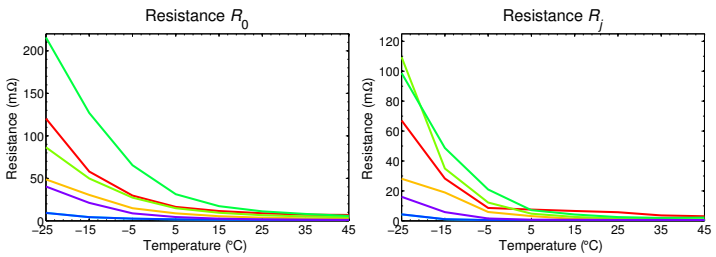
- The figure shows an overlay of true and model-predicted voltage over the entire 10 h test.



- RMS difference between the true and model results was 5.37 mV in this case.
- Zoom more clearly shows that circuit model captures cell performance quite well

Example results (1)

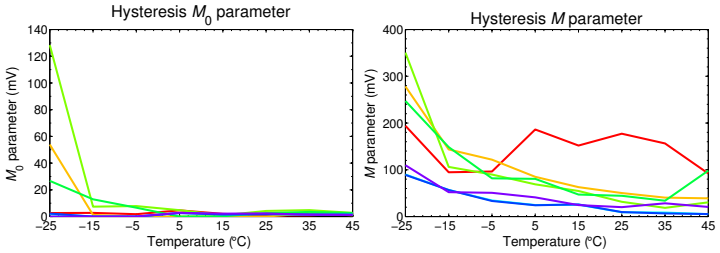
- Optimized temperature-dependent parameter values for seven different cells are shown in the following (tests at 10 C° steps)
- ESR R_0 decreases exponentially with temperature
- A near-universal result: any model lacking this feature is suspect



- Resistor–capacitor resistances R_j also decrease (roughly) exponentially as temperature increases. This is also expected

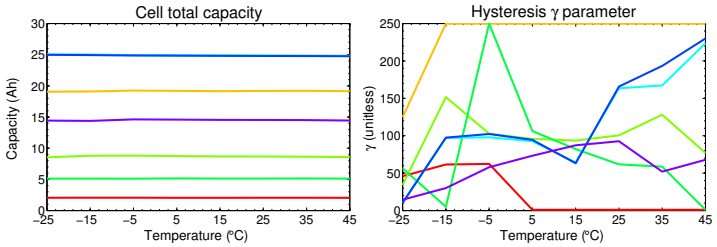
Example results (2)

- Optimized temperature-dependent parameter values for seven different cells are shown in the following (tests at 10 C° steps)
- Hysteresis levels generally decrease in magnitude as temperature increases
- True for both the dynamic and instantaneous contributions



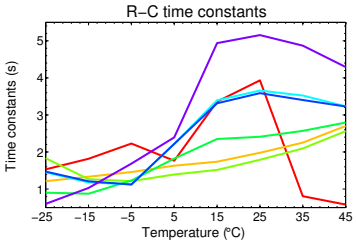
Example results (3)

- Optimized temperature-dependent parameter values for seven different cells are shown in the following (tests at 10 C° steps)
- The measured capacity is very nearly constant across temperature (as it should be)
- Hysteresis is generally "speeding up"
- That is, a smaller change in SOC is required to effect a large change in the hysteresis state



Example results (4)

- Optimized temperature-dependent parameter values for seven different cells are shown in the following (tests at 10 C° steps)
- Resistor–capacitor time constants tend to increase with temperature
  - This might actually seem a surprising result, as we would expect the cell dynamics to speed up at warmer temperatures
  - However, study of physics-based models teaches us that time constants can vary unpredictably with SOC and temperature



Summary

- You have now seen ESC models representative of actual lithium-ion battery cells
- These models work very well at the temperatures for which they are optimized
- In practice, the model will need to be evaluated at other temperatures as well
  - Linear interpolation is used to approximate parameter values from tables made via the parameter-identification process
  - This assumes a smoothness in the functions as temperature varies. We don't always (*i.e.*, rarely) see this from the initial system-identification output
  - Some hand smoothing of parameter relationships is usually necessary to make models that match measured data nearly as well as the automatically tuned versions, but which work better at intermediate temperatures