Dynamic Pricing of Battery Warranties

Dependence on factors, modeling battery capacity decline to aid in pricing a portfolio of warranty payouts on lithium-ion batteries .


San Francisco
Chicago
New York
Houston
Capacity
Time

Factors

Battery capacity decreases over time and the main factor that affects the rate of battery degradation is the ambient temperature. The effect of temperature on degradation has been well studied and modeled as a stress factor that accelerates the ongoing degradation process. Degradation processes are accelerated by Temperature Stress Model "S(T)" and SOC (state of charge) Stress Model S(σ).

We couldn't find a reliable approach to measure S(σ) stress factor which takes specific gravity as inputs to aid in assessing the state of charge, so we decided to use temperature stress factors.

Temperature Stress factor S(T)

We used a research paper and found that the stress factor for temperature is derived from the Arrhenius equation, which models the temperature dependence of the rate of a chemical reaction:

$$S(T) = e^{k_T(T-T_{ref})\cdot\frac{T_{ref}}{T}}$$

value of the temperature stress coefficient kT and values of the reference temperature Tref are defined in the research paper.

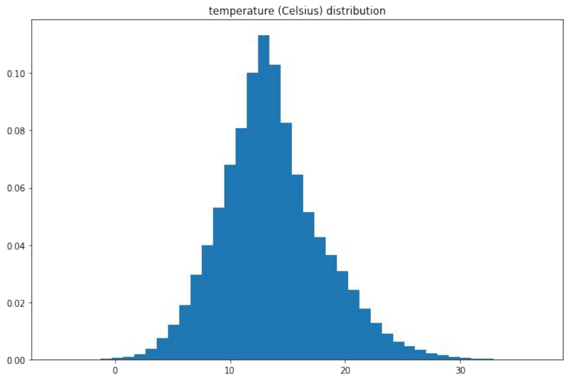
S(T) modelling

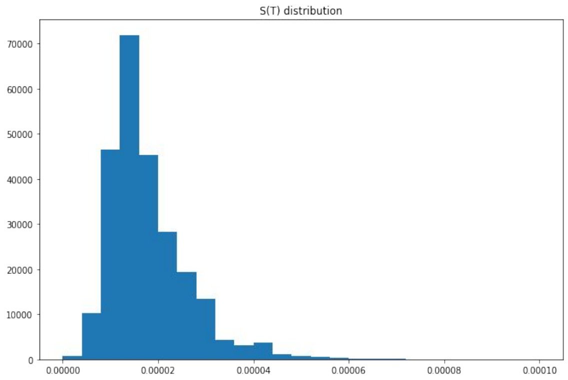
We use the temperature in the city of San Francisco to model temperature stress factor S(T).

In the graph we can observe:

- temperature distribution
- S(T) distribution

used to simulate factor values and capacity decline.



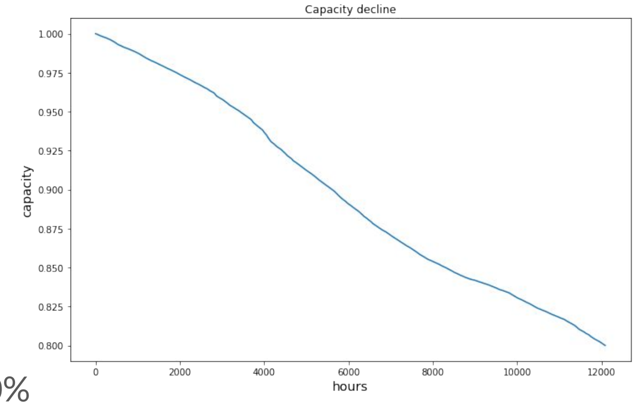


Simulation of capacity decline

We determined the function of capacitance decrease over time using the temperature stress factor:

$$Capacity_t = 1 - S(T)_t$$

$$Capacity_{\ t+1} = Capacity_t - \ S(T)_{t+1}$$



We also simulated the decrease of the capacity over time,
the result of the simulation we can see in the graph on the right.
The capacity decline is not smooth but , maybe including
more cities than just the city of San Francisco
might give a smooth capacity decline curve.
Moreover, we are also including a cut off at the point of 0.8 as 80%
of the remaining capacity because capacity decline beyond 80% is irrelevant.