

Health and Performance Characteristics of Used Electric Vehicle (EV) Battery Packs

Corey Tyree¹, Paul Leufkens¹, Alyssa McQuilling¹, Dagmar Becker¹,
Peng Yu², Surinder Singh²

¹Southern Research, Birmingham AL; ²NICE America, Mountain View, CA

Problem Statement:

The market for second use EV batteries is poised to grow rapidly as new EV fleet generations go into service. These batteries have a significant amount of residual capacity after their vehicle life has been completed and can be repurposed for various other use case application, e.g. energy storage solutions behind the facility meter. This poster will present a data-driven analysis of state-of-health and performance found in a population of used EV battery packs.

Introduction:

- Repurposing of batteries offers an economic alternative to recycling or disposal of used EV batteries and offers a longer lifetime
- Used batteries are expected to be available for a significantly lower price point than new batteries enabling more and larger energy storage system deployments
- Figure 1 shows the EV market and a range of EV models from the past several years
- Table 1 highlights key parameters for a population of used EV battery packs from model year 2011 that have been evaluated for use in an energy storage system

Electric Vehicle Models in 2008-2013

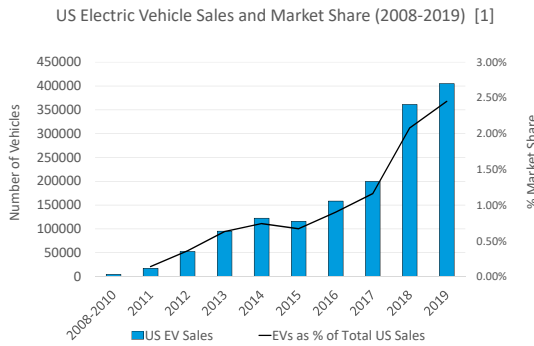
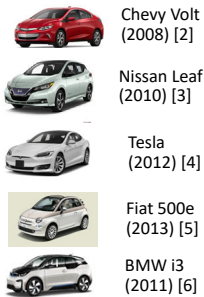


Figure 1. EV Sales from 2008-2019 [1]

Table 1 – ID and use data of 13 battery packs under test				
Pack #	Manufacture Date	Return Date	Mileage	State of Health (SOH)
#01	5/2011	9/2017	49,000	8
#02	5/2011	4/2017	26,000	8
#03	1/2011	9/2017	51,000	8
#04	6/2011	4/2017	45,000	8
#05	3/2011	4/2018	40,000	8
#06	6/2011	8/2017	43,000	8
#07	8/2011	9/2017	48,000	8
#08	4/2011	9/2017	48,000	8
#09	7/2011	6/2018	52,000	8
#10	7/2011	4/2017	33,000	8
#11	3/2011	1/2018	34,000	9
#12	5/2011	4/2017	26,000	8
#13	7/2011	1/2018	16,000	8

Battery Pack Qualification before system integration:

- The initial phase of this project involved the evaluation of the remaining capacity available in the used EV packs under test.
- The vehicle manufacturer considers the original battery management unit (BMU) in a battery pack as IP, thus the BMU is modified before a pack can be purchased and the state of health and state of charge determination is complicated.
- Cycle tests were performed using a range of charging and discharging voltage and current settings to determine the rest discharge capacity and ascertain the battery's remaining useful life.
- Packs underwent two charge cycles (discharge, rest, charge, rest, discharge, rest, and charge) from a voltage limits of 290 V to 395V (a safe approximation for 5 and 95% state of charge (SOC)); the capacity and voltage during a typical test are shown in Figure 2.
- New battery packs had a capacity of 24 kWh, having a 33 A discharge level at the maximum allowed 1C; current limits for second use however were defined based on a 16 kWh full C level with a maximum discharge current of 22A.

Results and Analysis:

- Table 2 lists the cycling test parameters.
- Figure 2 shows voltage and energy capacity of a single cycle test.
- Figure 3 summarizes the remaining pack capacity.
- Round Trip Efficiency for all cycle tests was $\geq 97\%$.
- Variations observed in pack capacity measurements resulting from different charge/discharge schemes were limited ($<10\%$ difference)
- There is no apparent relationship between the second life discharge capacity and its former life mileage or state of health (SOH)

Table 2 –Cycling Test Parameters				
Parameter	Standard	Wide Voltage Limits	Reduced Max Current	C-Rate Scaled Current
Min Discharge Voltage	290 V	289 V	290 V	290 V
Discharge Current	33 A	33 A	17 A	22 A
Max Bulk Charge Voltage	390 V	390 V	390 V	390 V
Bulk Charge Current	16.67 A	16.67 A	16.67 A	11 A
Max Absorption Charge Voltage	393 V	393 V	393 V	393 V
Absorption Charge Current	6.67 A	6.67 A	6.67 A	4.4 A
Max Finishing Charge Voltage	395 V	396 V	395 V	395 V
Finishing Charge Current	3.33 V	3.33 V	3.33 V	2.2 A

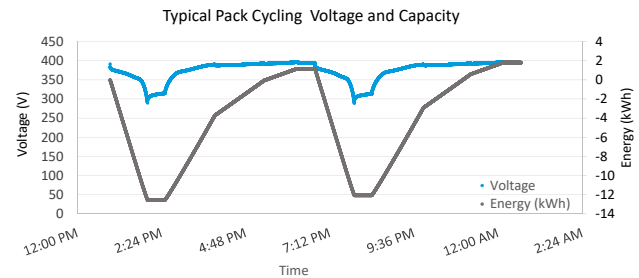


Figure 2. Sample Cycling Time series of Voltage and Energy Capacity

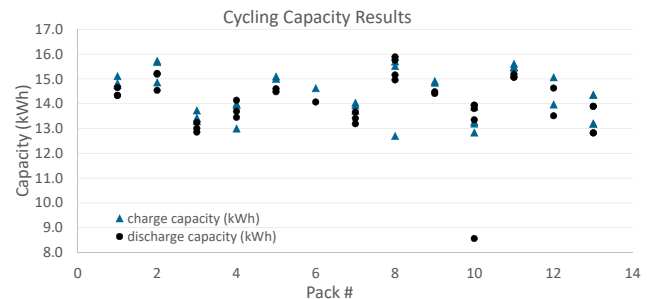


Figure 3. Summary of Pack Capacities Measured during Cycling

Conclusions:

- These battery packs have a high Round Trip Efficiency of at least 97%.
- Used EV batteries of the tested generation have lost almost half of their original capacity and the C-rate has been adjusted accordingly.
- New BMU solutions have to be found to address the limited visibility of SOC and SOH due to the resale process
- The next step of this project will be to integrate these packs into an Energy Storage System and subject that to use case testing.
- This testing will show how the combination of batteries with different capacities influences overall system performance.

References

- Based on data from: GoodCarBadCar.net, Inside EVs, Auto Manufacturers Alliance, IHS Markit, and Automotive News; Chart based on article by Loren McDonald on EVAdoption.com
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