Fundamentals of EV Battery Application & Optimising Longevity

The Electric Vehicle [EV] Battery and their usage in numerous types of vehicles have become increasingly vast with technology advances reinforcing durability, price and overall performance.

Aside from conventional lithium ion battery technologies, there are other battery technologies now represented: Solid state, aluminium ion, lithium sulphur, Lithium Polymer and metal-air.

Consumer confidence in EV is essential with supporting infrastructure, solid and stable grid supply as well as accessible OEM support. The crux for potential EV buyer concern is the travel range and re-charge duration. Although optimised technology has introduced reasonable performance, the fundamentals of battery energy storage systems must be conveyed in easy to understand and thorough methods to reshape the thought process in owning and driving an EV.

Australian Grid System supplied within the tolerated frequency deviation band is between 49.75 Hz to 50.15 Hz 99% of time with no contingency load event and 47.0 Hz to 52.0 Hz with multiple contingency event respectively.

In Victoria, the Frequency Operating Standards require that, during periods when there are no contingency events and no-load events, the frequency be maintained within the range 49.85 to 50.15 Hz for 99% of the time, with larger deviations permitted within the range 49.75 to 50.25 Hz for no more than 1% of the time.

Recharging EV Batteries with fast charge preference can be achieved within 15 to 30 minutes to achieve 80% state of charge [SOC]. In an ideal world, based on the 15-minute and 30-minute criterion, the frequency must depart from normal progression of 50 mHz for more than 15 minutes, 100 mHz for more than 5 minutes and 200 mHz at any time. With lithium ion battery technology, the efficiency of the entire storage system is set at 90% for charging and discharging processes, mainly because of the power electronics and auxiliary systems measured in the control and management systems. Because the SOC is always changing when operating an EV, and there is no need to store energy for a certain amount of time, self-discharging is almost nil.

The end-of-life (time) (EOL) criterion is defined as the point when the battery state of health (SOH) falls below 80% of the nominal capacity of the battery, which is a commonly used estimate according to OEM's. The battery-aging is generally dependant on two main factors being superposition of calendric and cyclic aging. The capacity loss due to the two aging effects reduces the remaining capacity until the EOL is reached. The increase of the battery's inner resistance and a decrease in its efficiency are ignored because until the EOL is reached the changes are insignificant.

Calendric aging is dependent only on the time that has passed. Because of the low currents with charge values lower than 0.5C in minimal load application, the battery temperature would not rise more than 2 K. Some battery storage systems are climatic controlled whereas Avass Technology batteries under low c-rate conditions do not induce enough heating to increase the aging phenomena due to its unique coating resistance parameters.

Cyclic aging depends only on the depth of cycle (DOC) of the applied load profile with alternating charging, discharging, and idle time segments. The SOC range in which the battery is cycled does not change the resulting capacity loss through cycling.

Calendric aging occurs at any time, regardless of the C-rate [*measure of the rate at which a battery is discharged relative to its maximum capacity*]. However, cyclic aging depends on the DOC, the initial mean SOC of a cycle, and the C-rate, among other factors such as different power-to-energy (P/E) ratios and the resulting aging appearance. Whereas calendric aging shows no influence on the P/E ratio, cyclic aging has a different aging behaviour.

Deeper cycles result in more extensive aging, hence, for the same power, a larger battery pack has a decrease in aging compared to a smaller pack when the same load is applied. Heavy-duty aging (3000 cycles to EOL) results in a total aging of 3%. However, in optimistic scenario (14,000 cycles to EOL) results in only 1% aging. This difference is explained by the differences in cycle and calendric aging. When the cycle life is very weak, each equivalent full cycle has a significant impact on the overall aging processes. However, a high cycle life results in a decrease in cyclic aging, and only calendric aging occurs.

General cycle counting methods in various parameter sets are shown in below table.

Aging Index	State of Charge (SOH)	Full Cycles	Calendric Lifetime (years)
1 - Medium	***80 %***	***5000***	***15 years***
2 – Weak	***80 %***	***6000***	***15 years***
3 – Strong	***80 %***	***3000***	***12.5 years***
4 – Optimistic	***80 %***	***14000***	***20 years***

Battery pack sizing has a strong influence on the aging effects and degradation is derived from several factors, such as the DOC, mean value of the SOC, and the C rate, among others. In case of the larger battery pack capacity, the DOCs decrease, resulting in less capacity fading and smaller absolute values for the C rates.

In summary an increase in the cyclic or calendric lifetime leads to a decrease in aging. Additionally, the cyclic life and calendric lifetime are not linearly correlated to aging with the battery pack size. With faster charging applications 5% increase in DOC results in significant cyclic aging.

The effects of larger battery packs in EV applications when oversized by a factor of 1.6, will decrease aging from 3% to 1.8%. Since the overall P/E ratio changes, the aging decrease does not correlate with only the battery pack capacity. Therefore, an oversized system is not, in general, suitable for increasing the lifetime. A better cell quality, which is more expensive but has a higher lifetime expectancy, solves this problem.

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