A Study of the Factors that Affect Lithium Ion Battery Degradation

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Introduction

- Due in part to concern over atmospheric carbon and global warming, the move from centralized fossil fuel-based power generation to renewable energy-based distributed generation is growing.
- Since the availability of renewable energy, e.g., photovoltaic and wind, is independent of electrical demand, battery energy storage systems (BESS) are also under development.
- Several battery types have been studied for use in BESS, but for a variety of reasons, most new energy storage systems are based on lithium-ion (Li-ion) batteries.

Introduction

- Despite their advantages, Li-ion batteries degrade relatively rapidly under certain circumstances, which shortens their cycling lifespan, requiring costly replacement.
- This paper describes the results of an initial study of the influence of several factors on the degradation of Li-ion battery capacity during repeated charge/discharge cycling, including battery chemistry, ageing, cycling frequency, and temperature.

Experimental Details

- Two types of Li-ion rechargeable power cells were studied, the INR 18650-25R and the IMR 18650-HE2. Both batteries have the same size (65 mm long and 18 mm in diameter), maximum capacity (2500 mAh), and maximum charge/discharge currents (4A/20A), but different chemistries.
- The batteries were studied using an iCharger 1010B+ Synchronous Balance Charger/Discharger in Cycle Mode, to measure the decrease in battery discharge capacity during charge/discharge cycling.
- Measured data were recorded, plotted, and displayed using LogView, a suitable menu-based package.

Experimental Details

1. DC input 2. LCD screen 3. Function button 4. Cooling Fan 5. Temperature sensor port 6. Balance socket 7. Output port 8. USB port

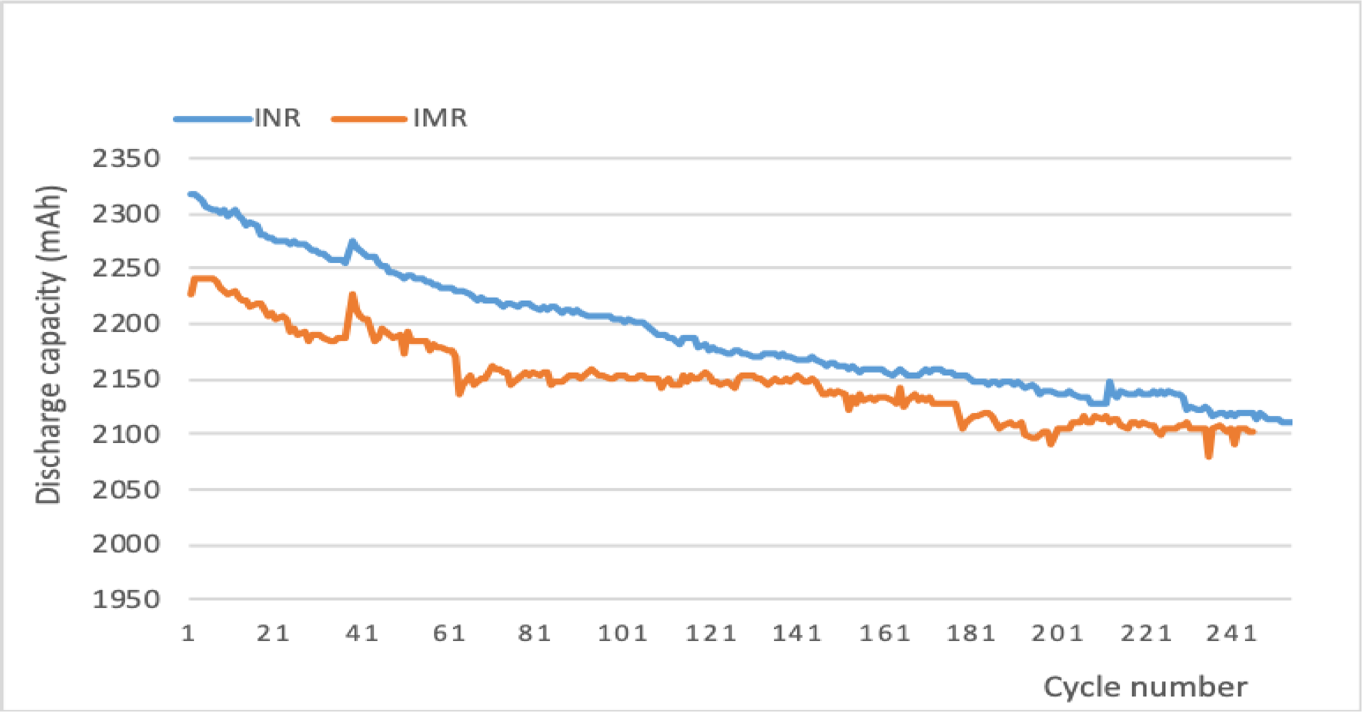
Experimental Details

- The traditional full charge and discharge (80% depth of discharge (DOD)) cycle method was used to study the effects of battery chemistry, ageing, temperature, and cycling frequency on battery capacity degradation.
- The standard charge process: constant current of 1.25A until the voltage increases to 4.2V (~ 3 hours). We used 2.5A.
- The standard discharge process: constant current of 0.5A until the voltage drops to 2.5V (~ 5 hours). We used 2.5A.

Results: Battery Chemistry Effects

- The INR battery: lithium nickel manganese cobalt (LiNiMnCoO2).
- The IMR battery: lithium manganese oxide ($LiMn_2O_4$).
- The cobalt and nickel should give the INR battery a higher specific energy (capacity) and longer lifespan compared to the IMR battery.
- New INR-25R and IMR-HE2 cells were charged to 4.2V and discharged to 2.5V 250 times at 27˚C, with 2.5A charge and discharge currents, with a 20-minute delay between each charge and discharge.

Results: Battery Chemistry Effects



Measured decrease in discharge capacity of INR-25R and IMR-25 batteries over 250 cycles at 27˚C.

Results: Battery Chemistry Effects

- The INR battery has a higher initial discharge capacity than the IMR battery, as predicted.
- However, both batteries degraded to approximately the same discharge capacity at the end of the 250 cycles.
- Thus, if lifespan is defined in terms of a battery's capacity decreasing to a certain level, both batteries had approximately the same lifespan, which contradicts the expectation that INR batteries have longer lifespan.

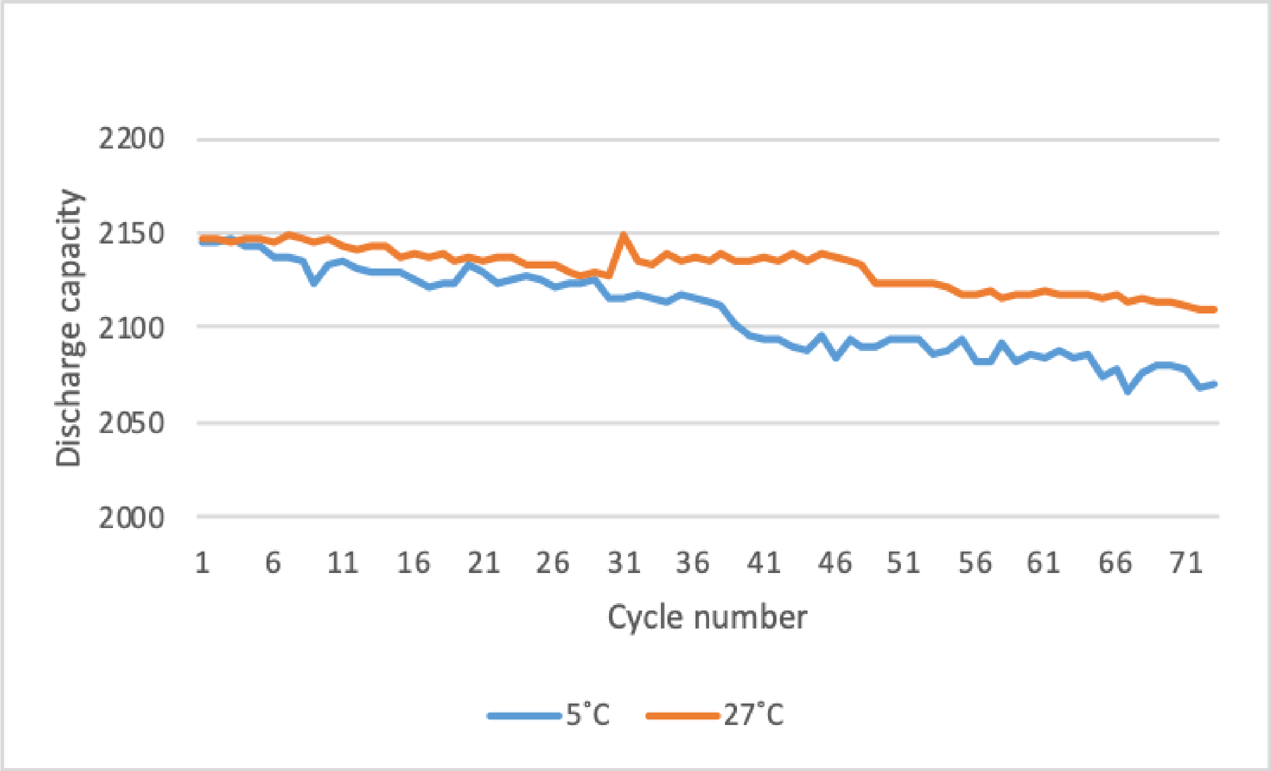
Results: Battery Ageing Effects

- An INR-25R battery was cycled once at the time of purchase, once again after two years in inactive storage.
- Charge/discharge currents were 2.5A/2.5A, charge/discharge voltages were 4.2V and 2.5V, and the temperature was 27˚C.
- The initial and final discharge capacities were 2409 mAh and 2142 mAh; thus approximately 267 mAh of capacity were lost during the two years of storage.
- This is more than the capacity loss during 250 cycles (208mAh) for the INR battery above. Thus, battery ageing alone can significantly shorten battery lifespan.

Results: Temperature Effects

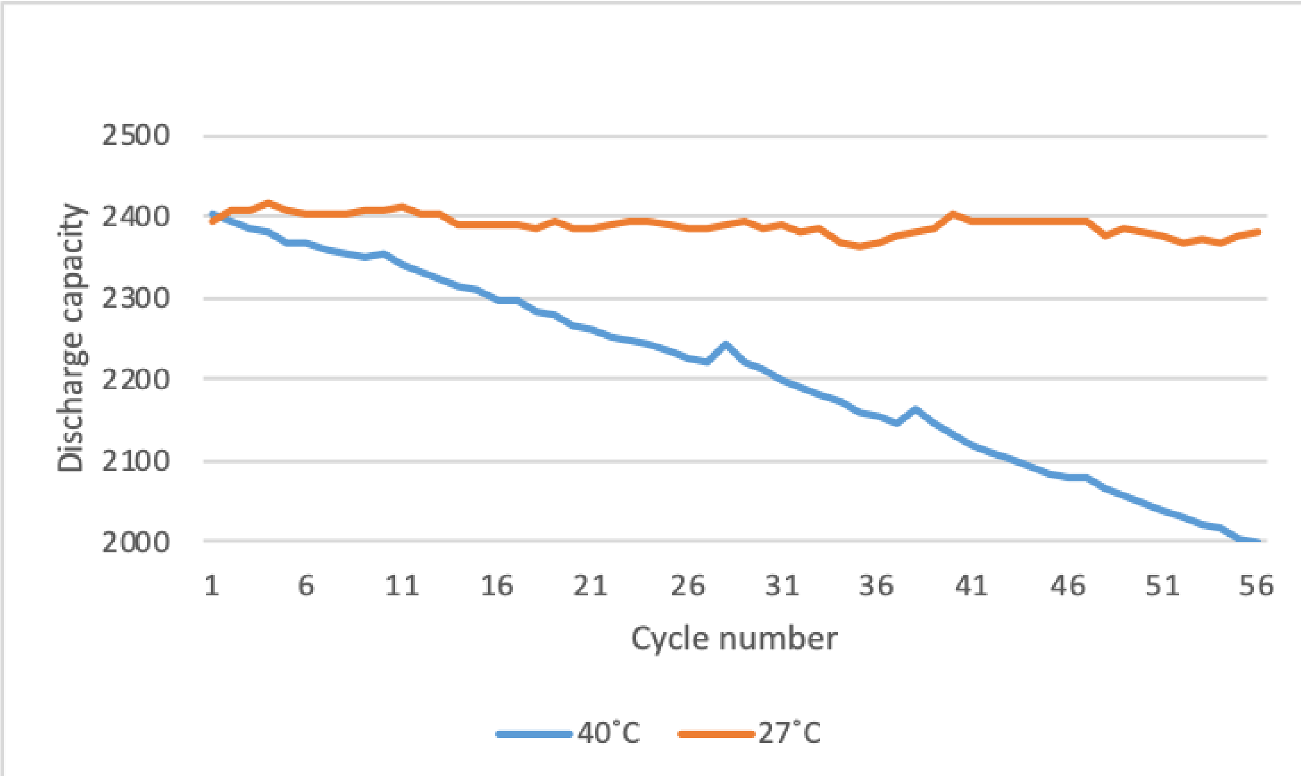
- It has been reported that Li-ion batteries function best at room temperature. To compare the dependence of battery lifetime on temperature, two INR-25R batteries were cycled, one at 27˚C and the other at 5˚C, and two others were cycled, one at 27˚C and the other at 40˚C. In all cases, 2.5A charge/discharge currents were used, the charge-discharge voltage range was 4.2-2.5V, and a 2 minute delay was provided after each charge and discharge.
- Next two slides show the results

Results: Temperature Effects



Measured decrease in discharge capacity (in mAh) of INR-25R cells at 27˚C and 5˚C over 70 cycles.

Results: Temperature Effects



Measured decrease in discharge capacity (in mAh) of INR-25R cells at 40˚C and 27˚C over 55 cycles.

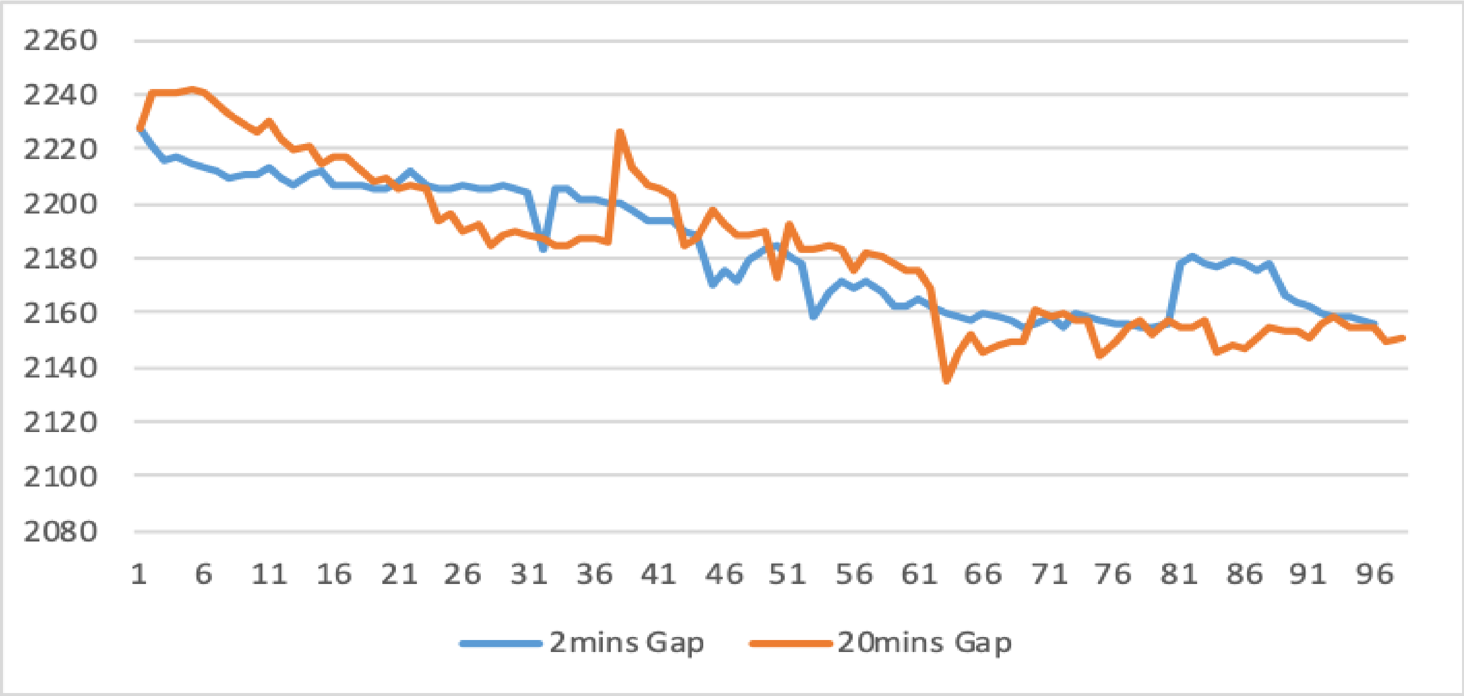
Results: Temperature Effects

- The battery cycled at 5˚C lost 3.5% of its capacity over 70 cycles compared to 2% for the one cycled at 27˚C.
- The battery cycled at 40˚C lost 16.7% of its capacity over 55 cycles compared to 1.3% for the one cycled at 27˚C.
- High temperatures can rapidly and significantly reduce Li-ion battery lifespan.

Results: Cycling Frequency Effects

- Frequent cycling of a battery without allowance for recovery during cycling can add stress to the battery, partially because of the temperature increase during cycling and insufficient cooling time. Thus, batteries that have longer recovery times during cycling should have slower degradation and longer cycle life.
- Two IMR-HE2 Li-ion batteries were cycled at 27˚C, with 2.5A charge/discharge currents, a charge-discharge voltage range of 4.2-2.5V, and with either a 2- or 20-minute delay after each charge and discharge.
- Both batteries experienced the same capacity loss after 100 cycles, meaning that, for these two cycling frequencies, the capacity loss was independent of frequency.

Results: Cycling Frequency Effects



Measured decrease in discharge capacity (in mAh) of two INR-25R cells at 27˚C over 100 cycles. Charge/discharge delay times were 2 minutes (blue curve) and 20 minutes (orange curve).

Conclusions

- The study gathered initial data on the influence of various items on the degradation of Li-ion battery capacity during deep (>80%) charge/discharge cycling.
- In the battery chemistry comparison measurement, the INR battery degraded faster than the IMR battery, as expected, but both batteries had approximately the same lifespan, contradicting the expectation that INR batteries have longer lifespan.
- In the battery ageing experiment, a battery that had been inert for two years lost as much discharge capacity as a new battery that underwent 250 charge/discharge cycles.

Conclusions

- In the cycling frequency experiment, with frequency determined by delay times of 2 minutes and 20 minutes between charging and discharging, the loss of battery discharge capacity was the same.
- The temperature dependence measurements showed that battery capacity degrades faster when the battery temperature is above versus below room temperature.
- Continuing measurements are being made with additional types of Li-ion batteries, e.g., lithium polymer and lithium titanate, other cycling frequencies, temperatures and charge/discharge currents.

Questions?