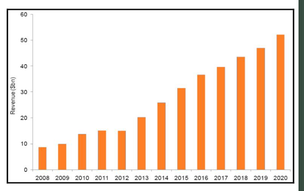
Integrated Battery Testing Solution

Centre for Mechatronics and Hybrid Technology
Mechanical Engineering, McMaster University
Rioch D'lyma

EECOMOBILITY (ORF) & HEVPD&D CREATE

Battery Overview

- Global Electric vehicle market estimated to reach $271 Billion (U.S Dollars) in 2019



- Batteries currently a major limiting factor on the road to electrification
- Li-Ion battery market expected to reach 50 billion by 2020

Limiting Factors

- Batteries currently a major limiting factor on the road to electrification
- Li-Ion battery market expected to reach 50 billion by 2020

- Neither a sensor to determine the capacity it can hold (State of Health)
- Most state of charge estimation techniques. Direct & indirect, are not adequately accurate in all scenarios

Testing Overview

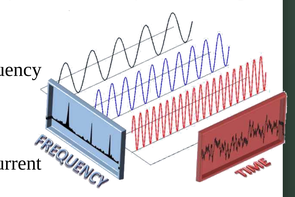
- Research is based around the 2 limiting factors, State of Charge & State of Health.
- Two promising test's are proving to lead the way:
  - Electro impedance spectroscopy (EIS)
  - Coulombic efficiency
- Drive cycle profiles are used to cycle the battery with current profiles similar to what an electric vehicle would demand

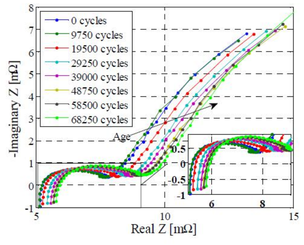
Coulombic Efficiency

- Allows for the ability to better predict a battery's longevity when compared to others at very early stages of testing
- This is accomplished by very accurately measuring the current flowing in & out of the battery
- Any loss of power between the process of charging & discharging can be attributed to the internal resistance and other disruptive processes and is used to determine a particular batteries longevity.

Electro impedance spectroscopy (EIS)

- Quick & Powerful way to get a snapshot of battery state at a given point
- Attainable by injecting a high frequency excitation signal into the battery
- Based on the voltage & current measurements the impedance is then calculated





Once plotted, we are able to identify patterns

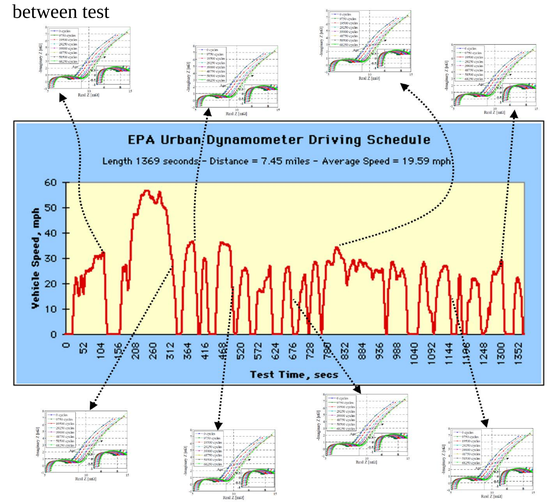
With distinct characterizations of both state of charge & state of health

Commercial implementation D&V

- In order to meet the demanding testing needs, D&V Electronics built a complete testing solution consisting of 3 modules:
- High Power Battery Cycler (100A)
- High Speed Signal Module (EIS)
- Coulombic Efficiency Module
- The system is designed for automatic sequencing between all 3 units, allowing for complete battery characterization with minimal user intervention
- The cycler units are stackable allowing for easily expandable power, up to 1600 Amps
- Built in battery models also enable parameterization of models during post-processing
- User friendly software allows for quick customization of test, complete access to results database with a number of easy to use post processing tools

Battery Characterization

- The D&V Battery Cell Tester and it's automatic sequencing capabilities allows for implementation of more advanced Testing Strategies
- New testing strategy being developed too allow for in-depth battery characterization
- Both Electro impedance spectroscopy and Coulombic efficiency test can be run during a number of points throughout a drive cycle profile
- No need for any intervention by the user to make connections or modify test allowing for a much larger number of points at which these test can be run
- This allows for a much more detailed tracking of a battery's internal characteristics such as state of charge, state of health, internal resistance etc.
- Immediately running these test within the cycle, also means a more accurate test of the battery as it does not allow the battery to settle between test



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