**Hybrid Pulse Power Characterization:**

Hybrid Pulse Power Characterization (HPPC) testing is intended to determine the dynamic power capability of batteries during both discharging & charging pulses over the useable voltage range and can be used as a parameter identification method for battery simulations. We have performed HPPC testing on two common lithium-ion cells (18650 and 21700 cells) at different temperatures and for different pulse c-rates.

The details of testing schedule, the post-processing and the results are shown here:

• How HPPC test data can be used to create an equivalent circuit model (ECM) of the battery.

• Discovered how ECM can be used to represent the dynamic behaviour of a battery.

• Understand how to simulate and analyse the voltage and current response versus time.

• Exploring how ECM can be used for battery electro-thermal coupled (ETC) analysis.

In order to analyse the capacity of different cells or different chemistry we perform capacity test at defined C-rate (0.5C as defined by manufacturer) at full SOC (100%).

**Cell Characterization Experiments:**

Characterization of each cell consisted of the following three stages:

(1) Capacity testing

(2) SOC–OCV testing, and

(3) Hybrid pulse power characterization (HPPC) testing.

Capacity tests consisted of three complete charge/discharge cycles at 1C-rate.

SOC–OCV tests consisted of a complete charge/discharge cycle at a C-rate of C/25.

Lastly, HPPC tests we perform according to the test profile.

At each SOC level from 0.1 to 0.9 with an interval of 0.1, a one-minute discharge/rest/charge pulse is run. The steps followed in the HPPC test as follows, it is beginning at a fully charged state:

1. Rest for 60 minutes (2) Discharge pulse at 1C for 10 s. (3) Rest for 10 min (relaxation period). (4) Charge pulse at 1C Or 0.75C for 10 s. (5) Rest for 10 min (relaxation period) (6) Discharge at 1C or at prescribed discharge C- rate (as per manufacturer datasheet) for 6 min (resulting in a 10% drop in the SOC). (7) Rest for 1 h. (8) Repeat steps (1 -7)10 times.

The capacity tests are performed to confirm the rated capacity of the cells, to ensure that the 1C-rate current is accurate. The SOC–OCV tests are conducted to establish the relationship between the SOC and the OCV.

**Cell Characterization Results:**

The SOC–OCV curves are constructed for each cell chemistry. The lower values of the OCV came from the discharging of the cells, whereas the higher OCV values came from charging. The average OCV values are to be used in the three ECMs as a parameter.