FEATURE SET EXTRACTION

Data collected from discharge cycles of Li-ion batteries cycled under various conditions are analyzed. The battery cycling data is provided by Prognostics Center of Excellence (PCoE) at Ames Research Center, NASA. The data repository contains capacity, voltage, current, temperature, current load and voltage load recorded for each discharge cycle of the batteries. Except the cell capacity, all other parameters are recorded over time during discharge; however these parameters are acquired with non-uniform sampling rate. It is observed that as battery ages there will be change in measured voltage, current and temperature. Hence it is paramount to extract the relevant features from these curves that are crucial in determining battery life. From each discharge cycle, a set of 8 parameters is extracted from voltage and temperature curves representing minimum and maximum values of each curve, and their respective times. In addition to above parameters, following 13 parameters are computed from voltage, temperature and current curves for each discharge cycle.

Capacity (Cap): The capacity of battery is computed by integrating discharge current over time and it is given by:

$$\mathrm{Cap} = \int_{t_1}^{t_2} I dt$$

Energy of signal (E): Signal energy of voltage and temperature curves are computed. In general, energy of signal is defined as the measure of signal strength over time and it is given by Eq.
Below:

$$E = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

where x(t) is the signal (either voltage or temperature) and t is time.
In this work VCE notation is used to denote energy of voltage curve
and TCE to denote energy of temperature curve.

Fluctuation index of signal (FI): Fluctuation Index of signal is defined as a measure of deviation of the signal from the mean and is given as:

$$\mathrm{FI} = \frac{\sqrt{\sum (y_i - \mu)^2}}{\omega}$$

where yi is the signal, μ is mean of the signal and ω is sampling
Frequency.

Skewness index (SI): Skewness Index is a measure of the extent to which a probability distribution of signal leans toward mean of the signal. This index is given by:

$$SI = \frac{\sum_{i=1}^{n} (y_i - \mu)^3}{\sigma^3}$$

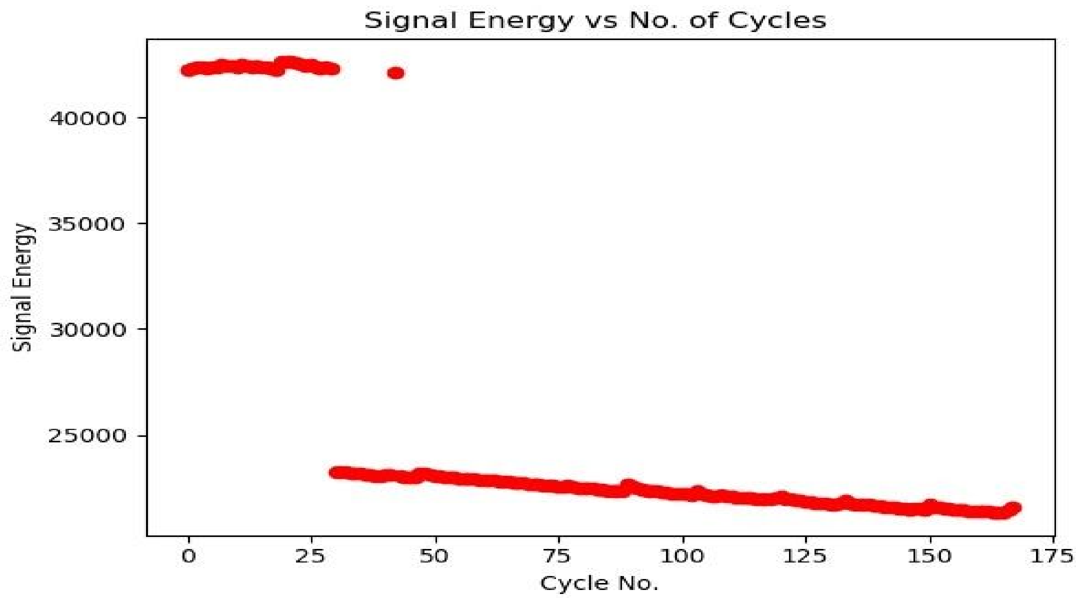
where yi is input signal l is mean of the signal and r is standard deviation of the signal and n is length of signal. Skewness index of voltage curve is denoted by VC_SI and that of temperature curve
is denoted by TC_SI.

Kurtosis index (KI): It is measure of the "peakedness" of the probability distribution of the signal and it is given by the
equation:

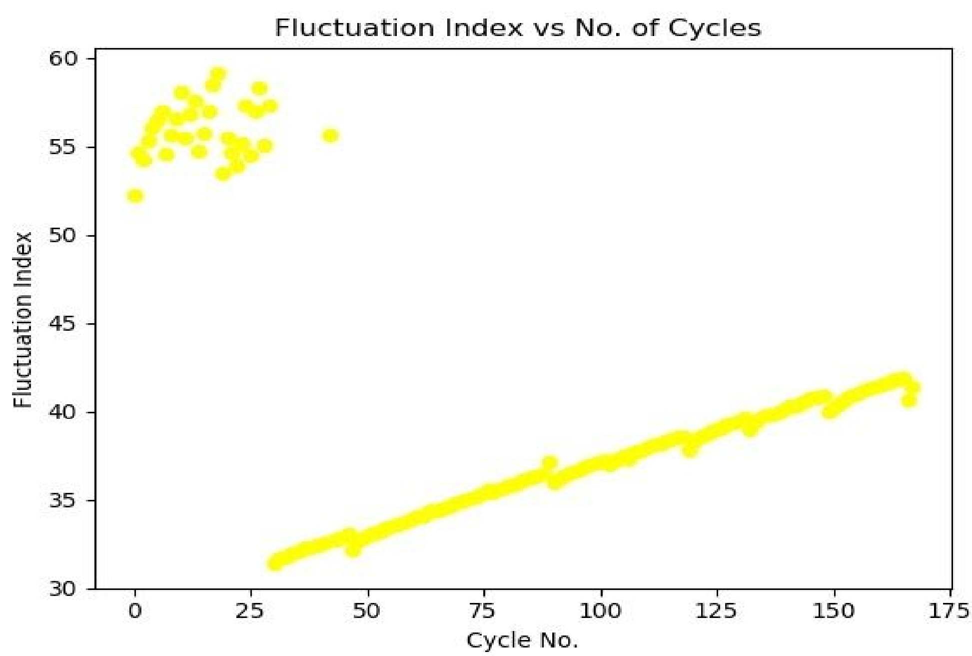
VC_KI and TC_KI notations used to denote kurtosis index of voltage and temperature curves respectively.

$$KI = \frac{\sum_{i=1}^{n} (y_i - \mu)^4}{\sigma^4}.$$

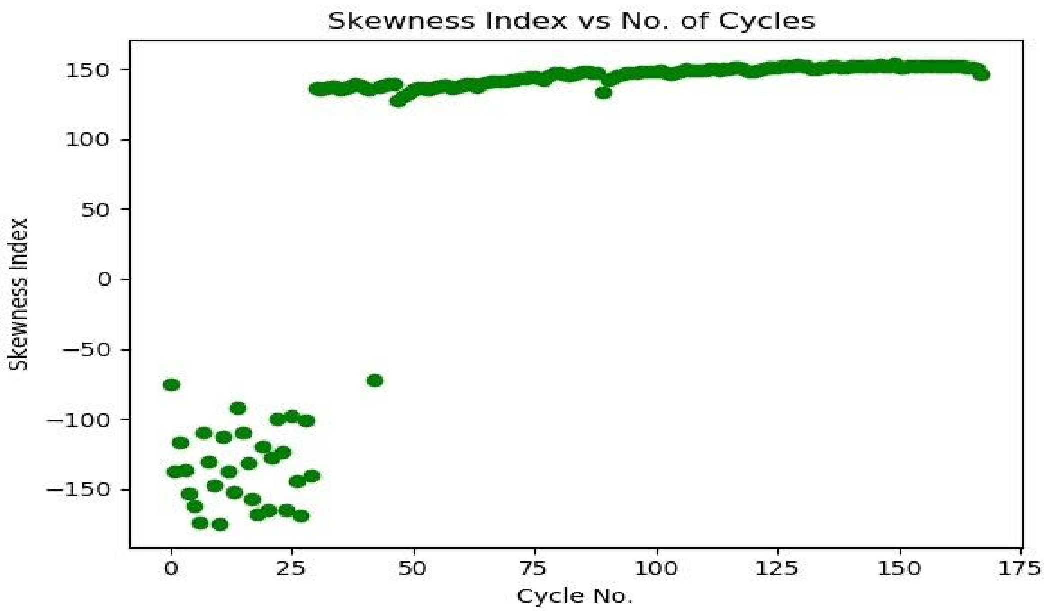
The graph below shows the signal energy and number of cycles . Initially the values of signal energy are constant But after 25 th cycle, the signal energy drops and then goes on decreasing showing a specific pattern.



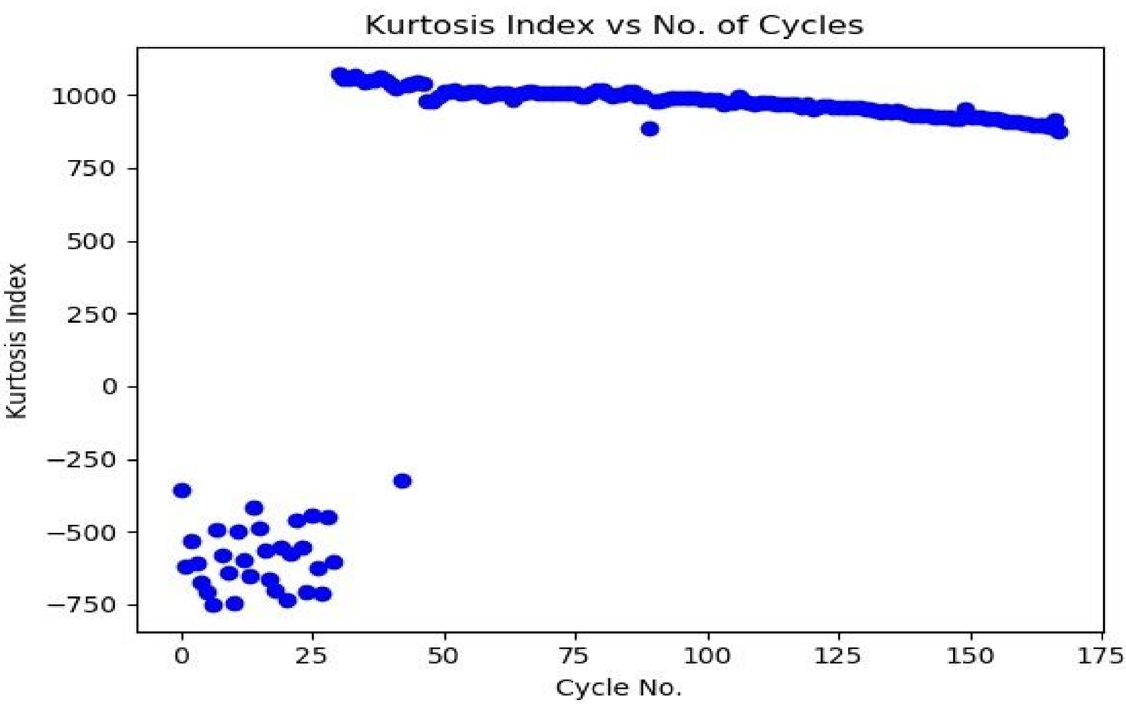
The graph below shows the fluctuation index and number of cycles . Initially the values of fluctuation index are scattered. But after 25th cycle the value the fluctuation index shows a sudden drop and then goes on increasing linearly with cycle number.



The graph below shows the skewness index and number of cycles . Initially the values of the skewness index are scattered. But after 25th cycle, the value increases suddenly and then remains constant.



The graph below shows the kurtosis index and number of cycles for battery B0005 . Initially the values of kurtosis index are negative and scattered. After 50th cycle value of kurtosis index is positive and maintain almost a constant value.



The python code and the generated csv are attached with the document.