**Round Trip Efficiency Estimation for Battery Energy Storage Systems**

**Introduction**

Battery Energy Storage Systems (BESS) are fast becoming common in both stand-alone and hybrid sites along with renewable energy sources like Solar and Wind. One of the critical Key Performance Indicators (KPIs) that needs to be tracked for BESS is the Round-Trip Efficiency (RTE).

**Definition**

To calculate the Round-Trip Efficiency the battery needs to be taken offline to do a full charge cycle. The process of estimating the RTE includes taking a fully charged battery, discharging it while measuring the Energy Delivered and then charging it again to 100% and measuring the Energy Received. The RTE for the cycle is then calculated as the Energy Delivered divided by the Energy Received.

**Problem formulation**

BESS operators want to calculate RTE for two main purposes; making sure that the battery is living up to its design specifications, and to track deterioration over time. At the same time, the operators cannot afford to disconnect the batteries to estimate the RTE.

Your task is to find a way to estimate the RTE for a given period based on the operational data from BESS (see description of data and the attached .csv file) and conclude whether it is performing according to its design specifications or not.

**Description of Data**

The attached .csv file contains the data from BESS operation. The data consists of four columns:

* **Timestamp:** The date and time of the measurement.
* **Energy Received:** The energy (in kWh) received from the power grid, which is delivered **to** the battery when the battery is being charged. In other words, this is the energy going **into** the battery. This signal is measured at a meter which means that the signal accumulates over time.
* **Energy Delivered:** The energy (in kWh) delivered to the power grid, which is taken **from** the battery when the battery is being discharged. This signal is measured at a meter which means that the signal accumulates over time.
* **SOC (State Of Charge):** State of Charge of the battery, meaning how charged the battery is. This value is average over the measured period, in this case it is average over 5-mins interval. The values range from 0% when empty to 100% when fully charged.

In addition to the above, the expected RTE according to the manufacturer’s specification is **86.5%**. The capacity of the battery has been incorrectly specified by the manufacturer and hence cannot be used.

**Our Expectation**

You are free to use python, R, Matlab, Excel, VBA or other similar tools that you are comfortable with. To convey your solution and results, we expect a script with description so that the script can be understood. Please include legible plots if you feel that they help in explaining the solution. Please make sure to clearly specify what assumptions and/or exceptions you have made and why.

A successful solution does not necessarily need to have the correct RTE number, but it is important the solution is conveyed in a clear and concise manner.

Time: We do not expect you to spend more than a maximum of 2 hours on this task.