ESS TEST BED EFFICIENCY TEST

Brief Description of the System and Test Results

An illustration of the laboratory set up, to conduct the experiment for calculating the efficiency of an emulated Energy Storage System (ESS), is shown in Figure 1. The Smart Grid Laboratory at Newcastle University where this experiment took place, is designed to synergistically combine the scale of simulation with the detail of experimentation. This is achieved through Flexible Power Conversion Systems (FPCSs), real and emulated ESS, and real-time simulation. For the purposes of this experiment, as shown in Fig. 1, an ESS emulator is coupled to a 415 V busbar of the laboratory network through a DC/ DC power converter and a DC/AC power converter.

For this experiments, the ESS emulator is used to represent a Li-Ion battery. The nominal voltage, power and energy rating of the battery can be fixed using the software interface of the emulator. In this experiment, SoC of the emulated battery is reported by the emulator, while power taken from or supplied to the emulator is reported by the DC/DC converter connected to its terminals.

In this efficiency test, the real power at the emulator's terminals is varied in steps of 25% at a time-step of 60 s, as shown in Fig. 2, 4, and 6. In these, positive power represents charging power and negative power represents discharging power. Initial SoC of the emulated battery is kept at 50% as shown in Fig. 3. Similarly, the test is repeated for other power & energy ratings of the emulator.

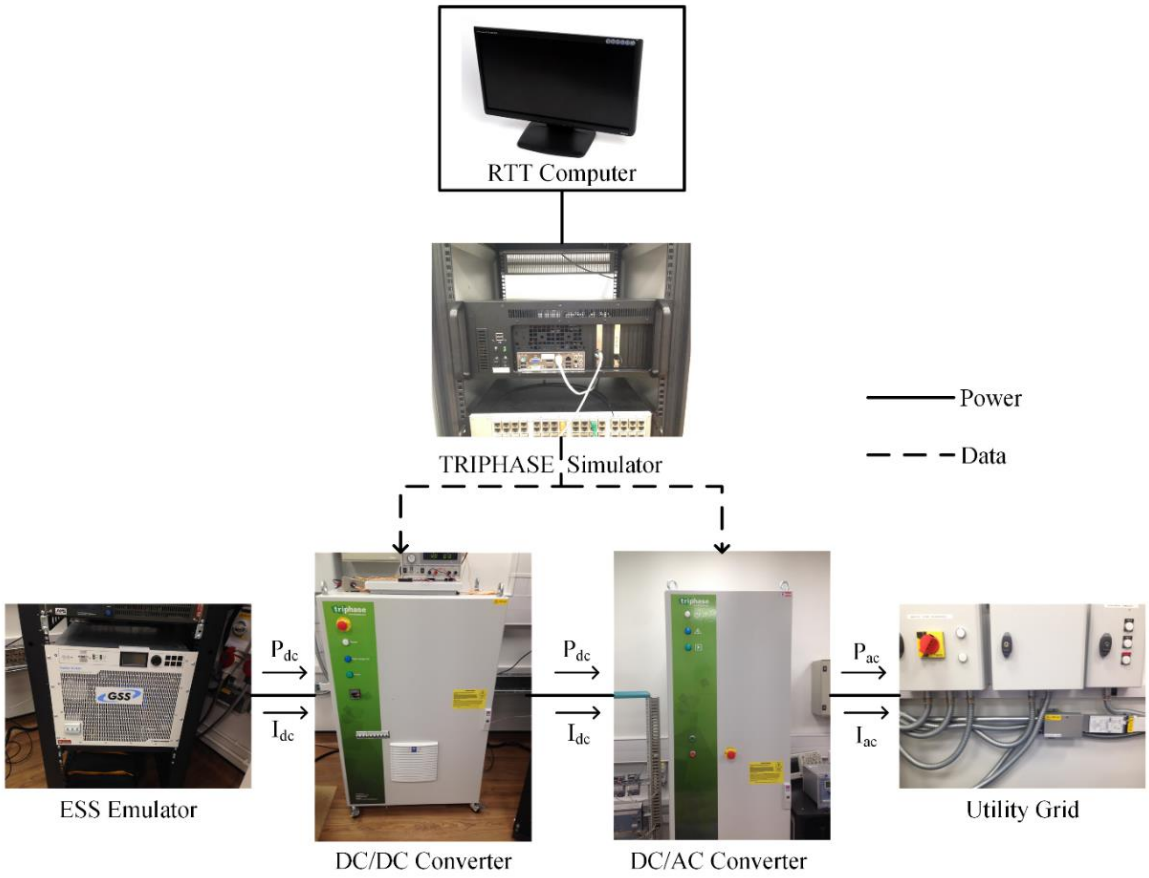

Figure 1: Emulated ESS Test Bed

Two separate csv data files are provided along with this document, one for power & the other for SoC. The powers & SoCs obtained for the battery emulator at different nominal voltage, power & energy ratings are shown below:

i) At 200 V, 1 kW, 1 kWh

To obtain these ratings, the voltage & ampere-hour ratings of a single cell of a Lithium-ion battery are chosen as follows:

Voltage of 1 cell = 4 V; Ah rating of 1 cell = 5 Ah; No of cells in series = 50

Thus, total battery energy rating = 50*4*5=1000 Wh = 1 kWh

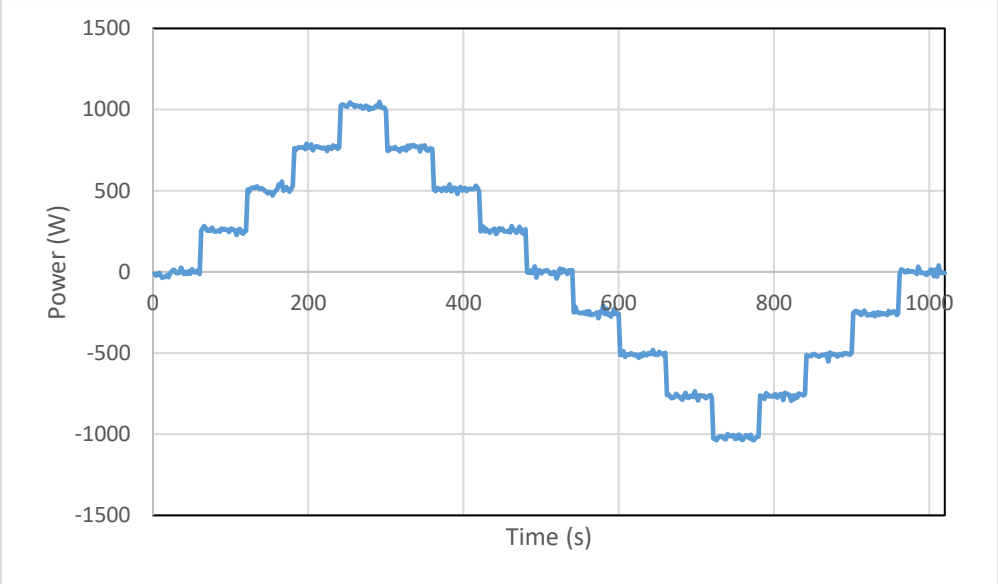

Fig. 2: Real Power Output of ESS Emulator

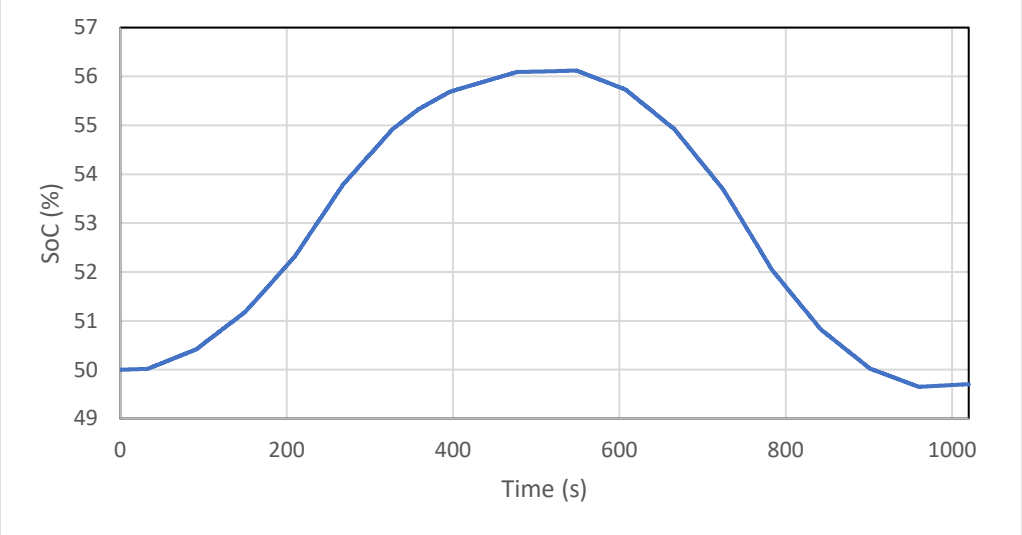

Fig. 3: SoC of ESS Emulator

The overall Round-trip Efficiency of ESS Emulator can be calculated as follows:

Round-trip Efficiency of ESS Emulator =ΔSoC (charge)/ΔSoC (discharge)=6.11/6.41= 95.3 %

where, ΔSoC is the difference between starting and ending SoC for each operation i.e. charge and discharge, in this experiment.

ii) At 400 V, 5 kW, 5 kWh

Voltage of 1 cell = 8 V; Ah rating of 1 cell = 12.5 Ah; No of cells in series = 50

Thus, total battery energy rating = 50*8*12.5=5000 Wh = 5 kWh

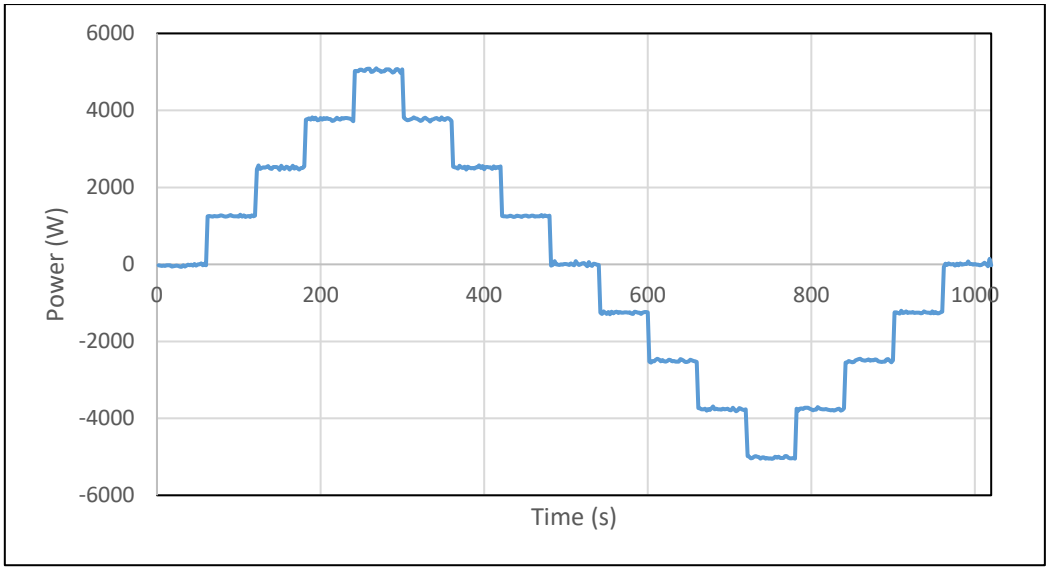

Fig. 4: Real Power Output of ESS Emulator

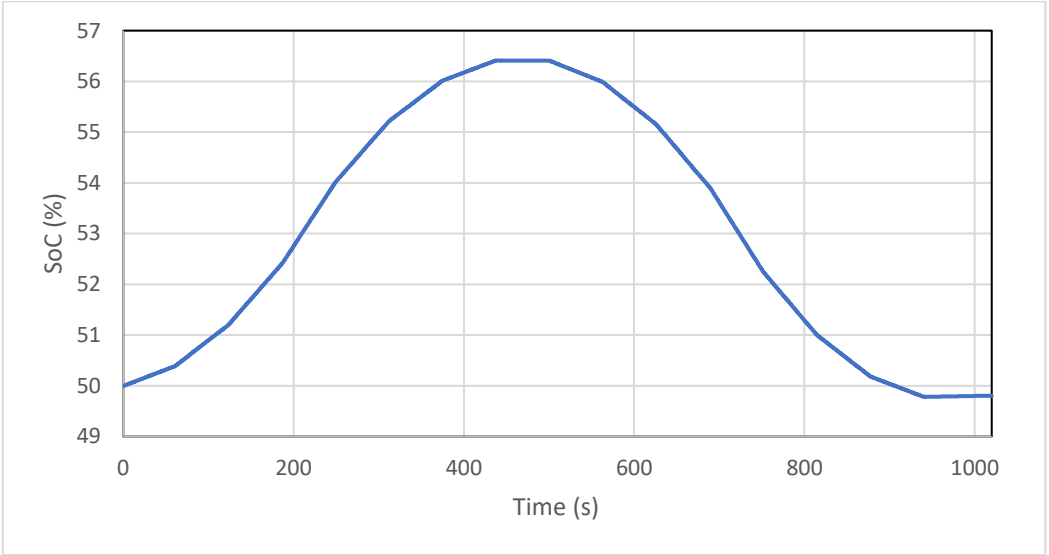

Fig. 5: SoC of ESS Emulator

Round-trip Efficiency of ESS Emulator = 6.41/6.61 = 96.9%

iii) At 400 V, 10 kW, 10 kWh

Voltage of 1 cell = 8 V; Ah rating of 1 cell = 25 Ah; No of cells in series = 50

Thus, total battery energy rating = 50*8*25=10000 Wh = 10 kWh

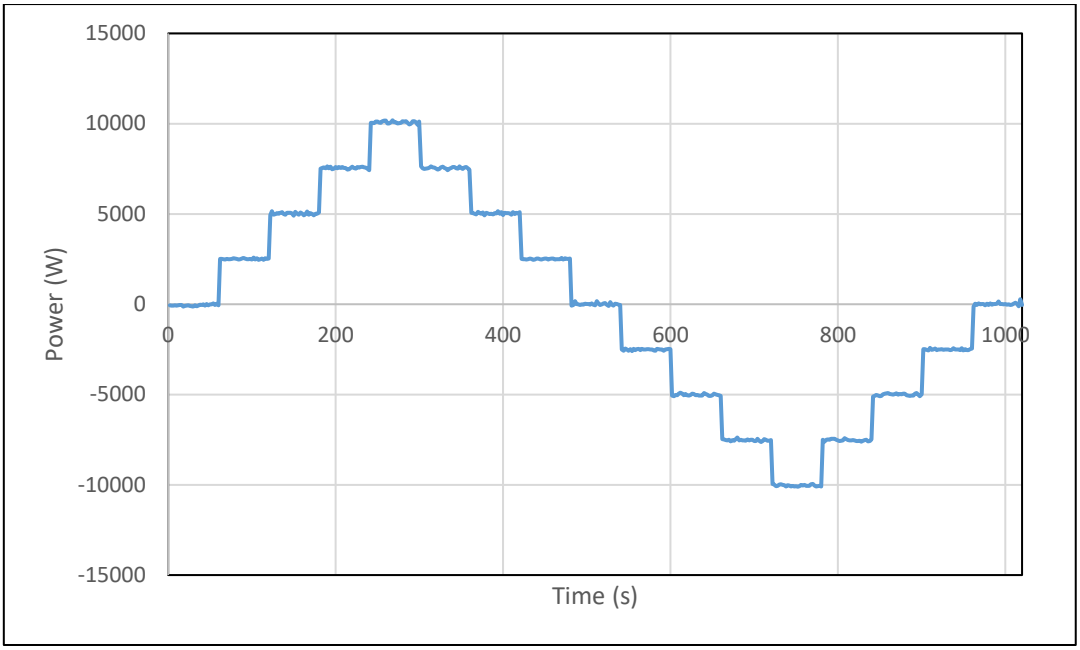

Fig. 6: Real Power Output of ESS Emulator

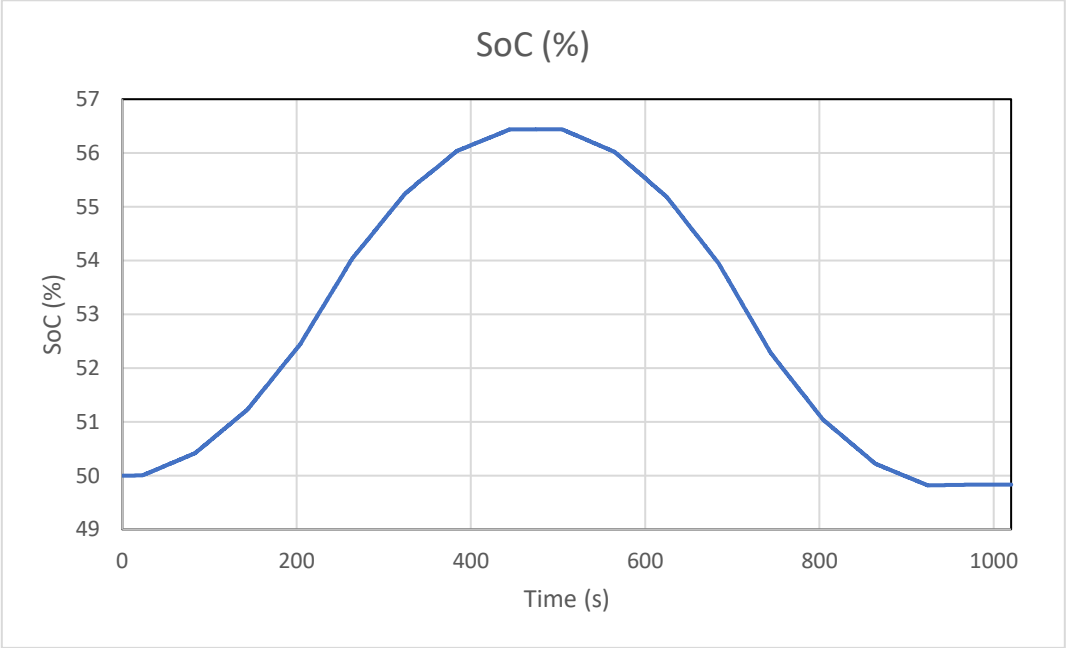

Fig. 7: SoC of ESS Emulator

Round-trip Efficiency of ESS Emulator = 6.44/6.60 = 97.5 %