ESS Calibration Test

Brief Description of the System and Test Results

The schematic of the facility where the tests are performed is shown in Fig. 1. It consists of two incomer transformers each rated at 11 kV/400 V, two isolation transformers each rated at 400 V/400 V, two inverters and three DC/DC converters, and a variety of energy storage assets. The following tests focus in controlling power flows between the grid and the supercapacitor bank rated at 90 kW, 2 kWh, 43.3 F & 650 V. In the existing set-up the maximum power of the DC/DC power converters is limited at 60 kW, however their rated power is 90kW. The AC voltage at the input and output side of the isolation transformer is 400 V and the voltage at the DC bus varies in the range of 650 V - 700 V.

To demonstrate control operations two tests involving real power are performed, one for short duration & high power, and the other one for long duration & low power. In the first test, the real power of Supercapacitors is varied in steps of 25% for a time-step of 20 s, as observed in Table 1 and Fig. 2. For the second test, the real power of Supercapacitors is varied in steps of 10% for a time-step of 2 minutes, as shown in Table 2 and Fig. 4. Similarly, another test involves changing the reactive power of the grid-coupled inverter in steps of 10% as shown in Table 3 and Fig. 6. The corresponding powers at the supercapacitor back terminals and its state of charge (SoC) are reported by the system and plotted in each of these tests. The SoC of the Supercapacitors is initialized at 0% as shown in Figs. 3, 5 & 7. Three separate .csv files corresponding to Tables 1, 2 & 3 are provided along with this document.

Some useful discussions regarding Supercapactor modelling and SoC evaluation can be found in the references [1], [2].

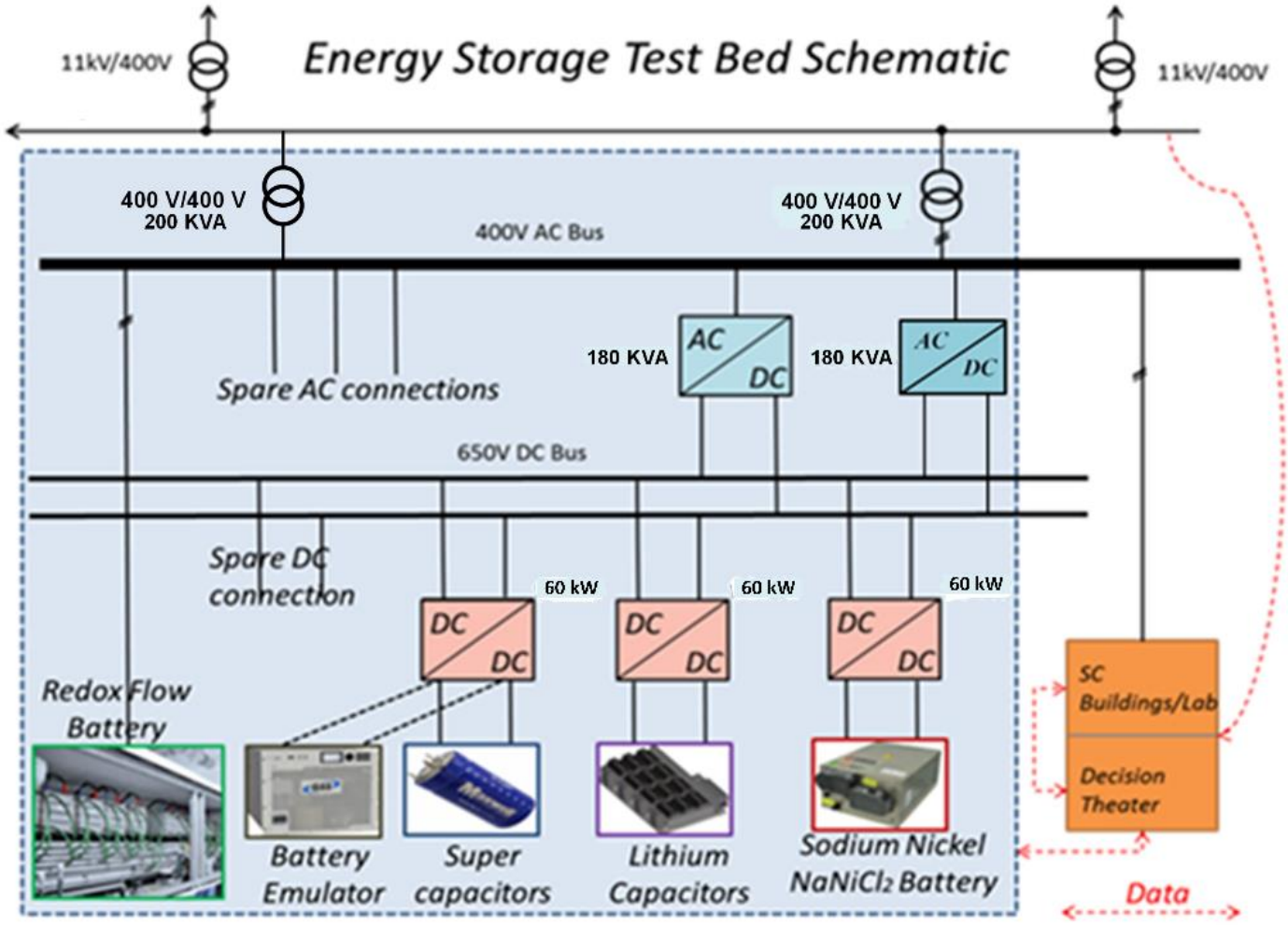

Fig. 1: Schematic of system under study

I) Real Power Calibration Tests

Active Power Nominal Rating = 60 kW

Maximum Active Power in this Case = 60 kW

Table 1: Real-power (*P*) Calibration Test for short duration & high power

Step-time (s)	Real Power (%)
0	0
20	25
40	50
60	75
80	100
100	75
120	50
140	25
160	0
180	-25
200	-50
220	-75
240	-100
260	-75
280	-50
300	-25
320	0

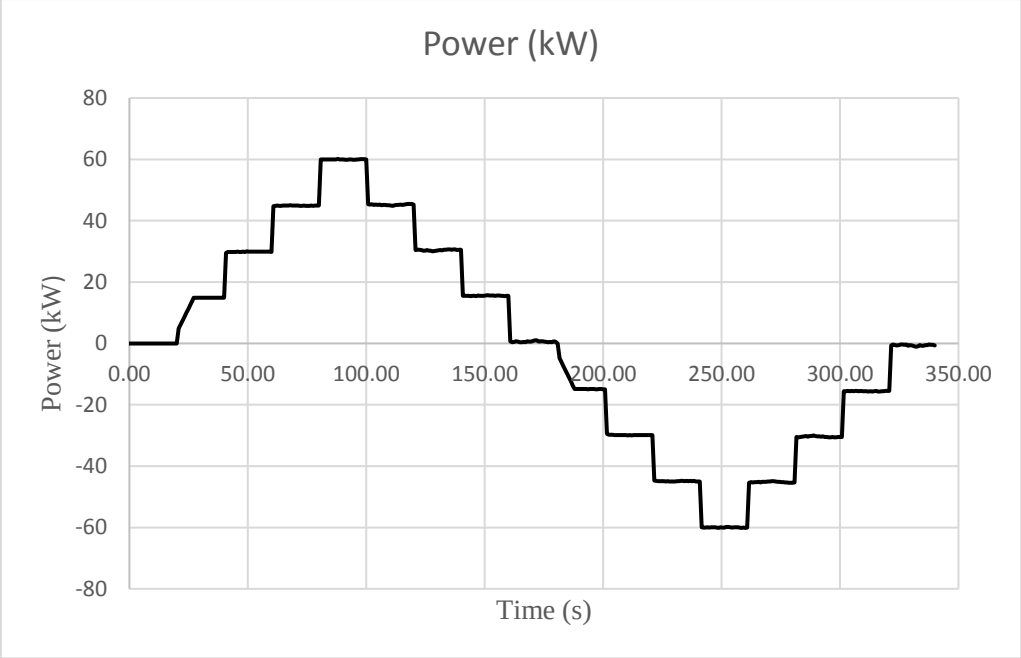

Fig. 2: Active Power Output of Supercapacitor (Positive Power for Charging & Negative Power for Discharging)

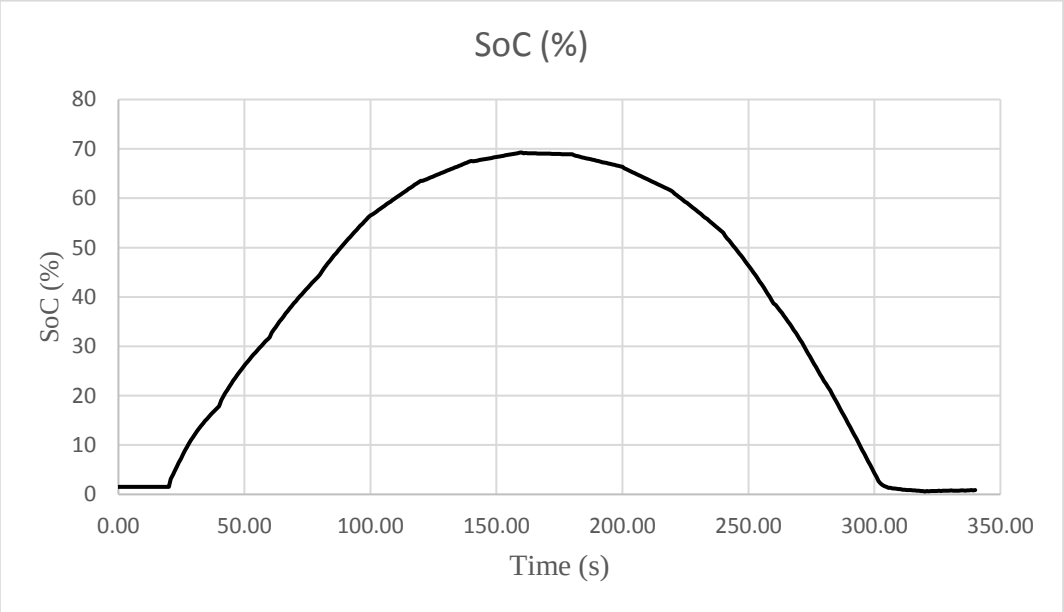

Fig. 3: SoC of Supercapacitor

Table 2: Real-power (*P*) Calibration Test for long duration & low power

Active Power Nominal Rating = 60 kW

Maximum Active Power in this Case = 10% of 60 kW = 6 kW

Step-time (s)	Real Power (%)
0	0
120	10
240	0
360	-10
480	0

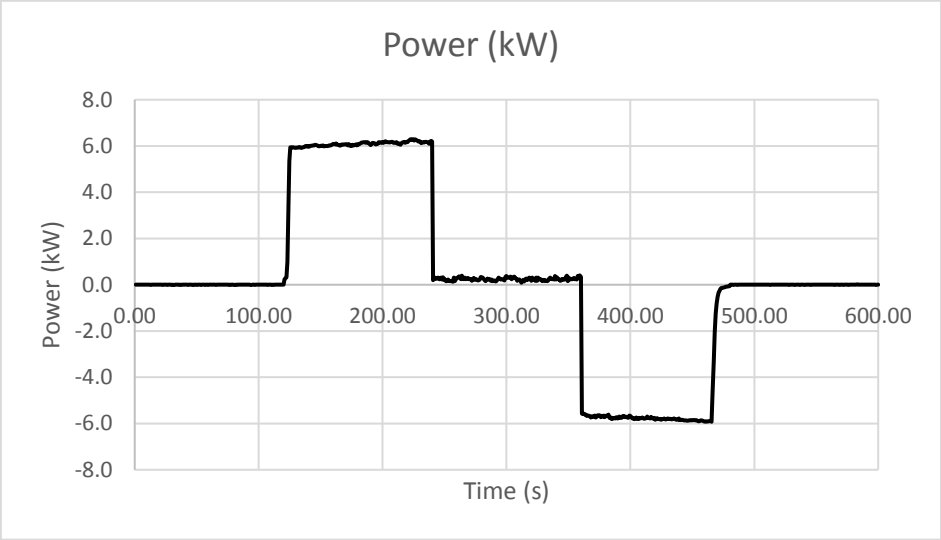

Fig. 4: Active Power Output of Supercapacitor (Positive Power for Charging & Negative Power for Discharging)

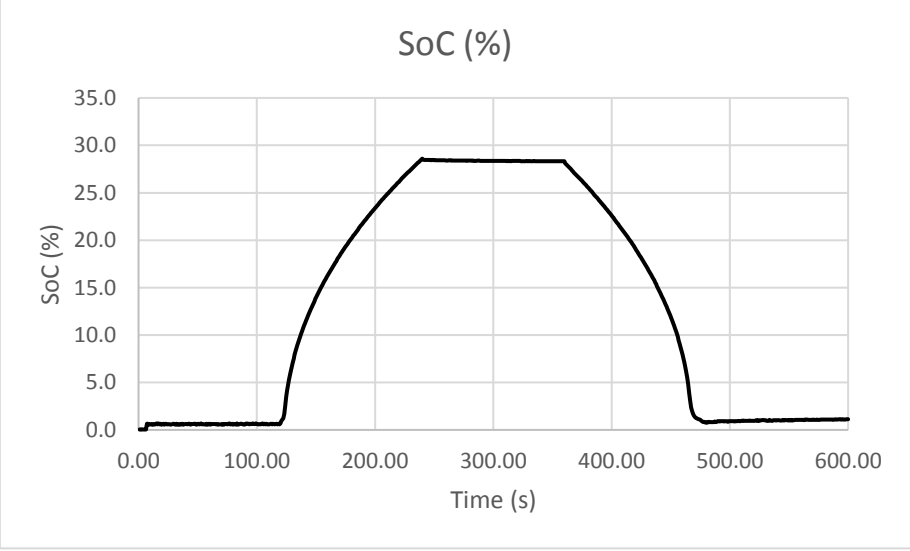

Fig. 5: SoC of Supercapacitor

II) Reactive Power Calibration Test

Table 3: Reactive power (Q) Calibration

Reactive Power Nominal Rating= 60 kVAr

Maximum Reactive Power in this Case = 10% of 60 kVAr = 6 kVAr = 6000 VAr

Step-time (s)	Reactive Power (%)
0	0
20	10
40	0
60	-10
80	0

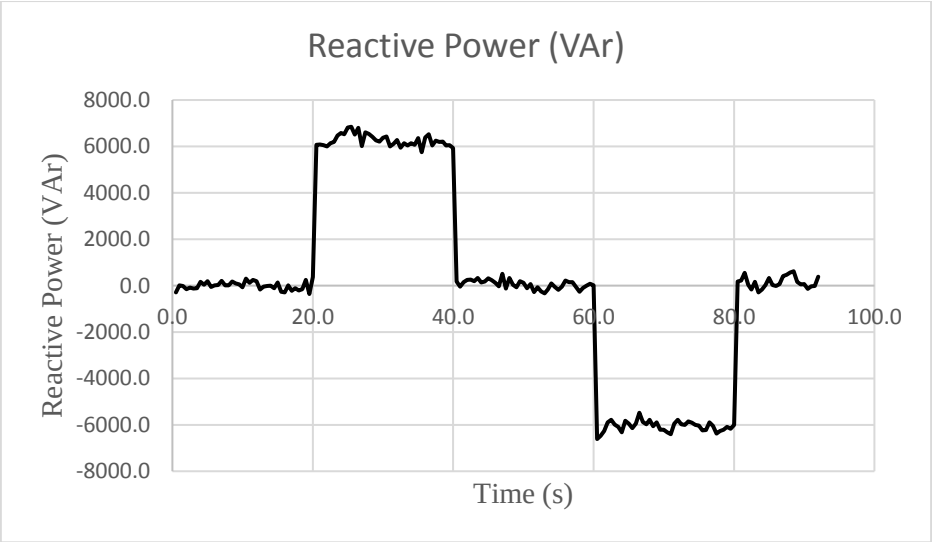

Fig. 6: Reactive Power Output of Inverter Coupled to Supercapacitor

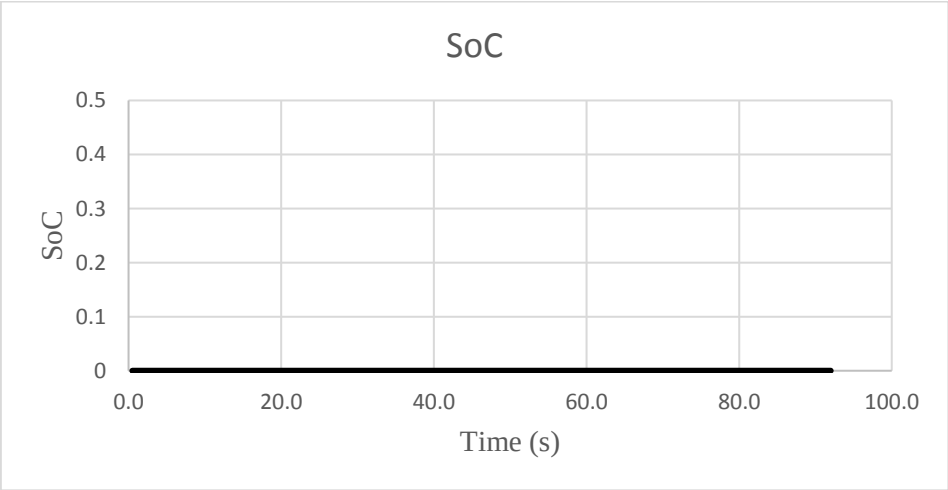

Fig. 7: SoC of Supercapacitor

References

[1] M. Ceraolo, G. Lutzemberger, and D. Poli, “State-of-charge evaluation of supercapacitors,” Journal of Energy Storage, vol. 11, pp. 211 – 218, 2017.

[2] A. Bostrom, A. V. Jouanne, T. K. A. Brekken, and A. Yokochi, “Supercapacitor energy storage systems for voltage and power flow stabilization,” 1st IEEE Conference on Technologies for Sustainability, pp. 230 – 237, 2013.