Electronic Supplementary Material (ESI) for Energy & Environmental Science

Perspective: Hybrid Systems Combining Electrostatic and Electrochemical Nanostructures for Ultrahigh Power Energy Storage

Supplemental Information

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Figure SI.1 shows the maximum V_{ESC} during the capture stage and V_{eq} as a function of V_{in} for the same C_{ECC} to C_{ECC} ratio matrix as shown in Figure 5. The maximum voltage is indicated by the dashed line, above which V_{ECC}(store) would be too large and cause electrolytic breakdown. V_{ESC} deviates from V_{in} when C_{ESC} and V_{in} is large, i.e. C_{ESC} = 150 μF and V_{in} > 4V due to the decreasing nonlinear internal resistance. V_{eq} decreases with increasing C_{ECC} and C_{ESC}. Comparing a single column (same C_{ECC}), V_{eq} increases with increasing C_{ESC} because Q_{ESC}(capture) is larger and more charge transferred results in higher potential across both capacitors. Comparing a single row (same C_{ESC}) where the amount of Q_{ECC}(store) is similar, V_{eq} must decrease for increasing C_{ECC}.

To explain provide a simplified explanation of this concept mathematically, in a circuit where there is no loss the charge in is given by:

$Q_{in} = C_{ESC} \times V_{ESC} = C_{ESC} \times V_{eq} + C_{ESC} \times V_{eq}$ and

Setting both equations for Q_{in} equal to each other, it is possible to solve for V_{eq} in terms of the capacitance values and is given by:

$V_{eq} = V_{ESC} /(1 + C_{ECC}/C_{ESC})$

Therefore, V_{eq} must increase with increasing C_{ESC} and decreasing C_{ECC}.

For C_{ESC} = 150 μF and C_{ECC} = 40 μF (lower left), V_{eq} rises above the maximum voltage (dashed line) where the voltage would be too large and cause electrolytic breakdown of the ECC. Operating in higher efficiency region (top right, see Figure 5) results in minimal increase in V_{eq} per pulse and raising the potential across ECC requires multiple pulses for additional capture-transfer-store sequences.

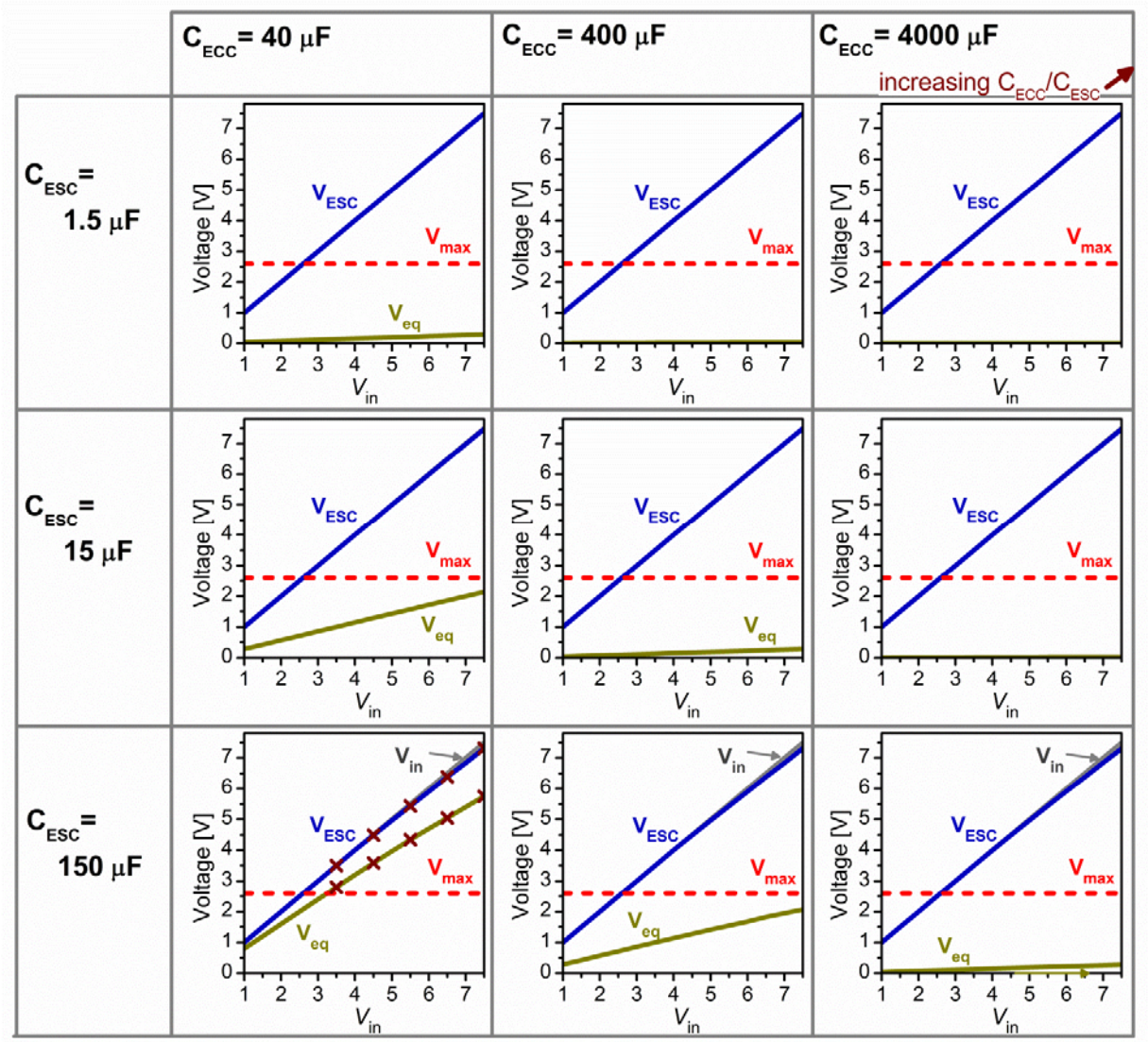

Figure S.I.1. The voltage across fully charged ESC from $t_2 < t < t_1$ (V_{ESC}) and equilibrium voltage after ESC transfers charge to ECC (V_{eq}) as a function of V_{in}. V_{max} marks the maximum voltage before electrolytic degradation occurs. ×'s indicate where $V_{eq} > V_{max}$. Rows have same C_{ESC} and columns have same C_{ECC}.