Design and Control of Battery/ Hybrid Energy Storage System for Frequency Response Grid Service

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1. Introduction
2. Design and control of HESS
3. Simulation result
4. Conclusion


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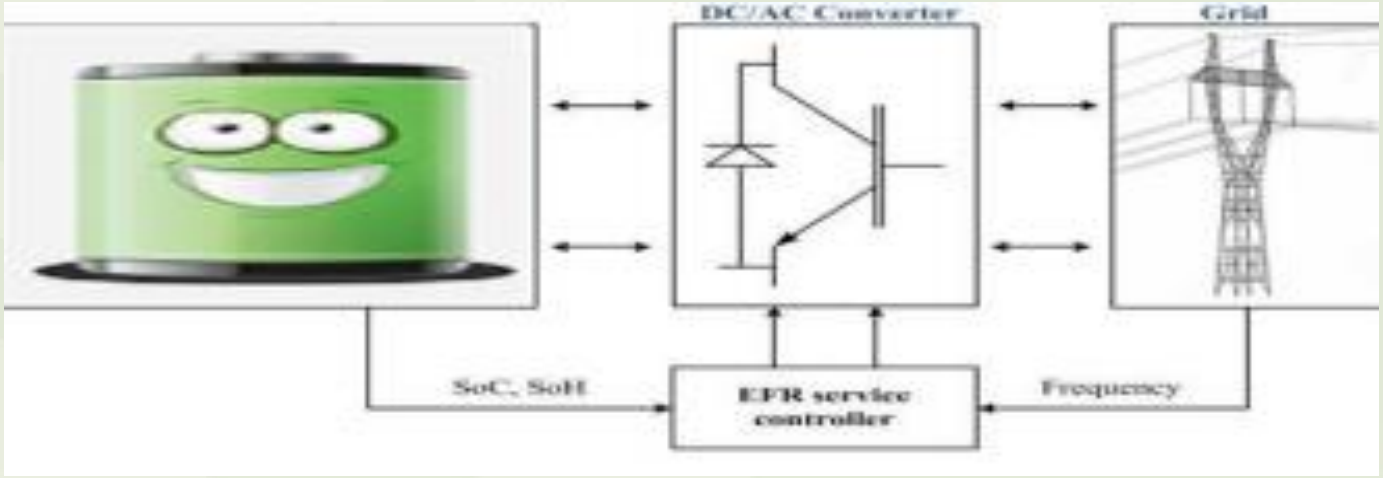


Figure: Grid connected storage system

- Ancillary service:
  - Secure Sustainable Electricity System
  - Reduce the impact of intermittent renewable generator
  - Expending energy market

- Enhenced Frequency Response (EFR):
  - Frequency support service / 1s response time
  - A 15min ability to provide a full power (Tmax)
  - Specified envelopes and zone
  - Up today 200MW are installed in UK (basically using LI-ion battery)

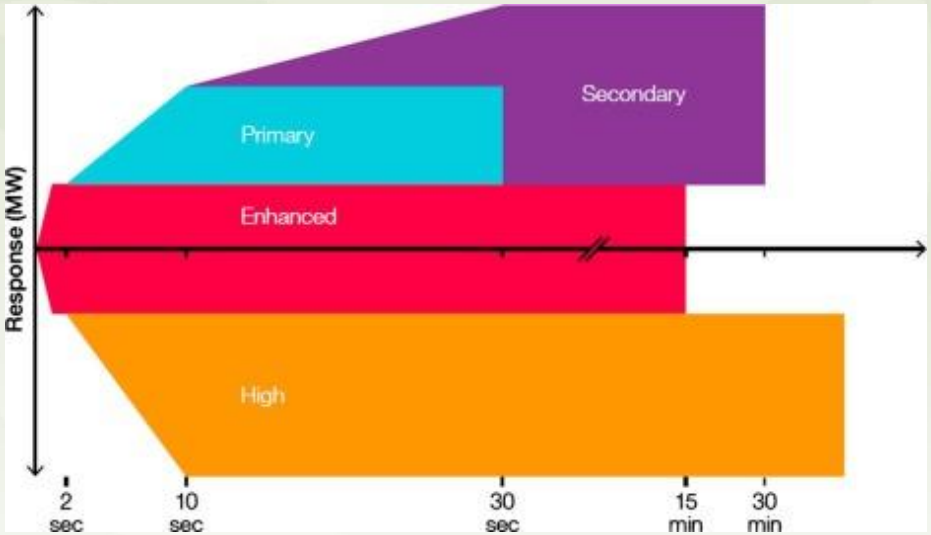


Figure: EFR concept

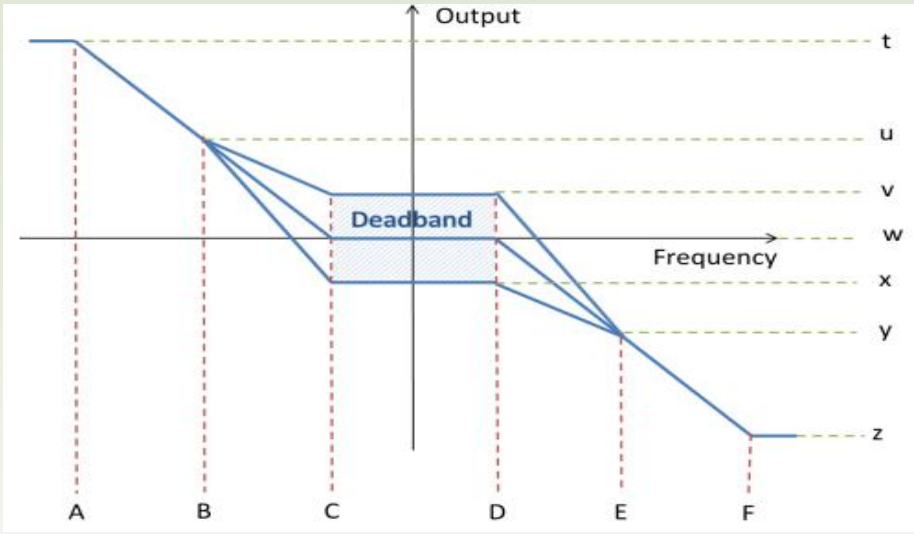
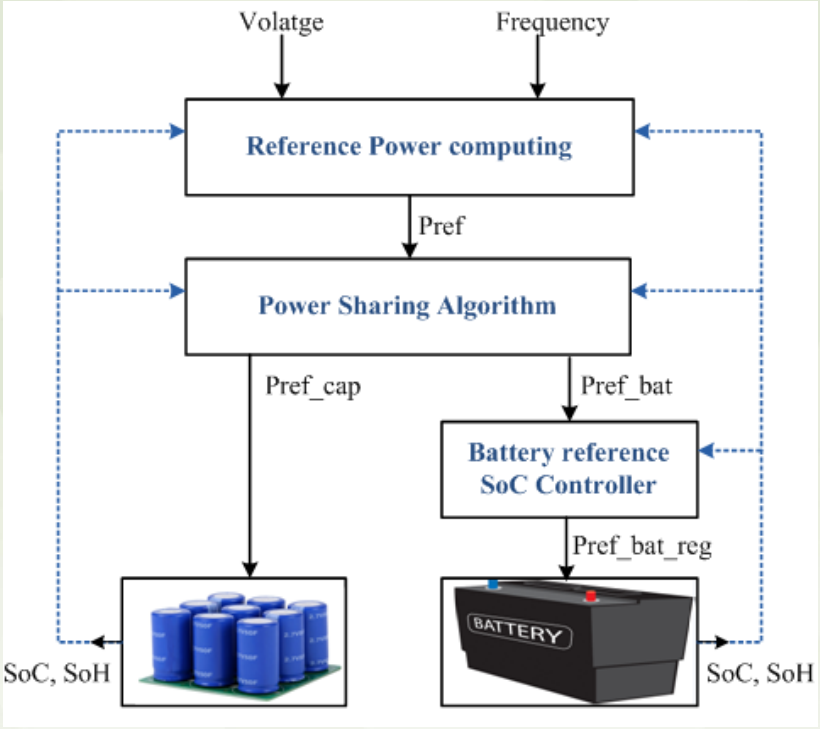


Figure: EFR envelope

Control and power management system design



Power management system structure

Control & Power management

- ✓ Reference Power computing block
- ✓ Power sharing algorithm block
- ✓ Battery reference SoC controller block

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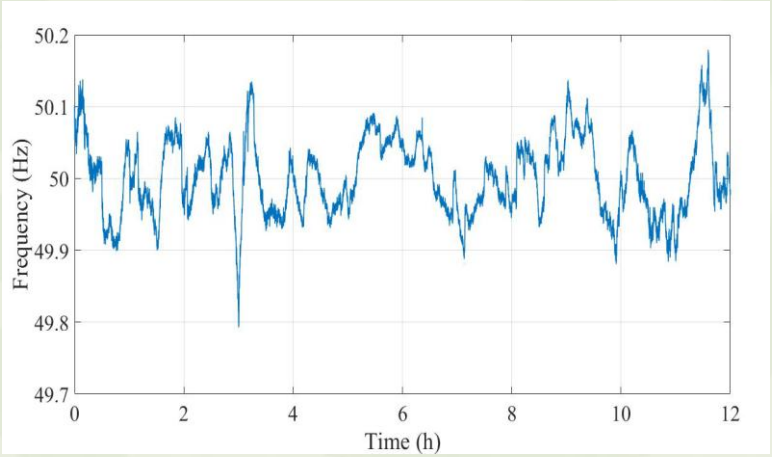
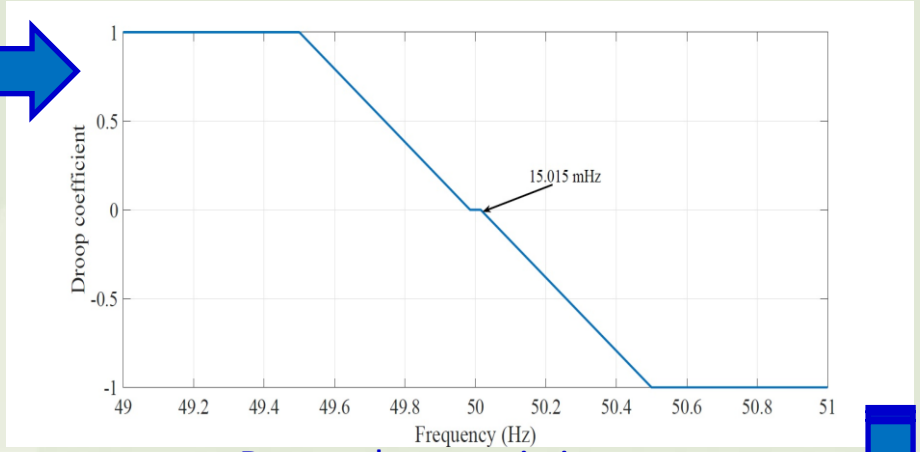
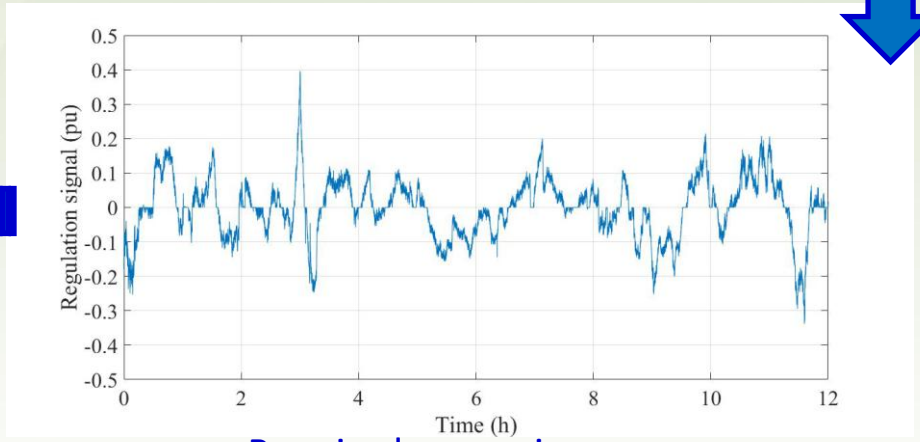
Reference Power computing



Frequency profile



Droop characteristic



Required power in pu

* Nominal power

Regulation Signal

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Power sharing algorithm

SC power reference signal: ⇒ $P_{ref-SC} = K_{sc} P_{ref}$ (7)

Battery power reference signal: ⇒ $P_{ref-bat} = (1 - K_{sc}) P_{ref}$ (8)

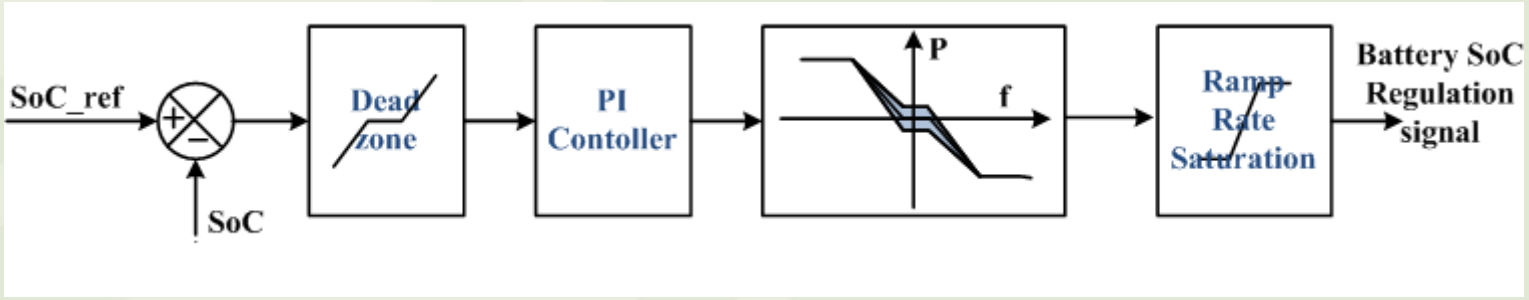
$$K_{sc} = \cos(k_{SC}^1)\frac{1+sign(P_{ref})}{2} + \sin(k_{SC}^1)\frac{1-sign(P_{ref})}{2} \quad (9)$$

$$k_{SC}^1 = \frac{V_{cap}^2}{V_{ncap}^2}\frac{\pi}{2}$$

V_{cap} : SC voltage.

V_{ncap} : SC nominal voltage.

Battery reference SoC controller



SoC controller structure

SoC Controller

- ✓ Dead zone block: minimize the battery use whenever the SoC value is within a certain range.
- ✓ PI controller: regulation of the battery SoC.
- ✓ A dynamic and a ramp rate saturation blocks: fulfill the TSO requirement.

(10)

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HESS design

Energy to be delivered during discharge operating mode

$$E_{HESS}^{disch} = \left(\eta_{HESS}^{disch}\right)^{-1} P_n T_{max} \quad (1)$$

HESS dischage effeciency

Energy to be stored during charging operating mode

$$E_{HESS}^{char} = C_{HESS}^{t} - \eta_{HESS}^{char} P_n T_{max} \quad (2)$$

HESS chage effeciency

Minimum instantaneous storage capacity

$$C_{HESS}^{tmin} = \left(\eta_{HESS}^{char} + \frac{1}{\eta_{HESS}^{disch}}\right) P_n T_{max} \quad (3)$$

Minimum initial storage capacity

$$C_{HESS}^{\min} = \frac{C_{HESS}^{t\min}}{\rho} \quad (4)$$

Battery end of life capacity index

Hybrid energy storage system (HESS) capacity distribution

$$C_{HESS}^{min} = C_{cab} + C_{bat} \quad (5)$$

Supercapacitor capacity

$$C_{cab} = pC_{HESS}^{min} \quad (6)$$

Hybridization capacity

Simulation results

System and control parameters

$P_n = 10MW$ $\quad SoC_d = 0.5\%$

$Kp_{Soc} = C_{bat}/10MWh$ $\quad Ki_{Soc} = 0.1$

$\eta_{HESS}^{disch} = 90\%$ $\quad \eta_{HESS}^{char} = 90\%$

Minimum HESS capacity: ⇒ $C_{HESS}^{min} = 6.2847MWh$

Refrence SoC value: ⇒ $SoC_{ref} = 55.25\%$

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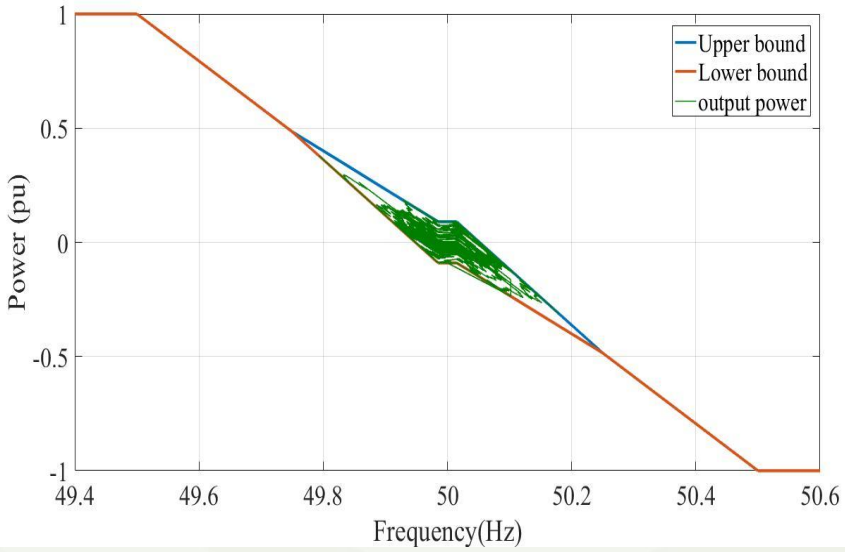
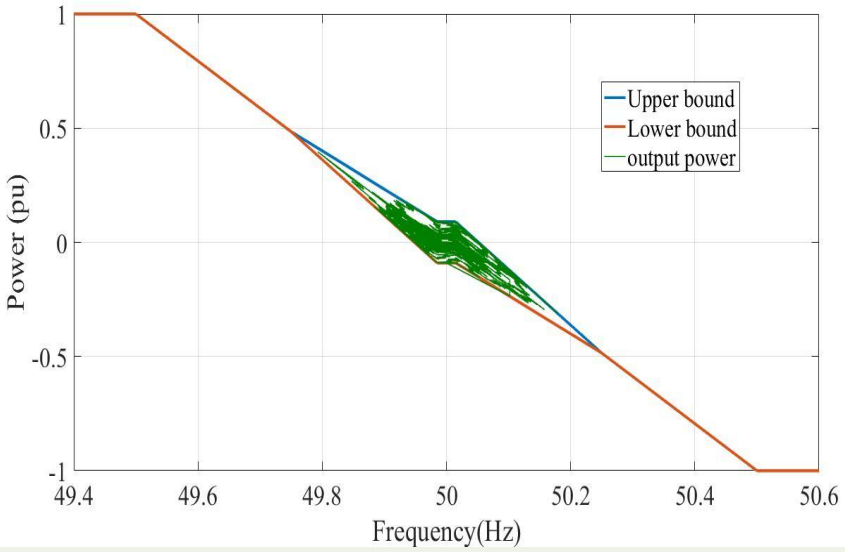
Simulation results

1 BESS system



2 HESS system p=3%



✓ Fulfillment of the EFR regulation portfolio.

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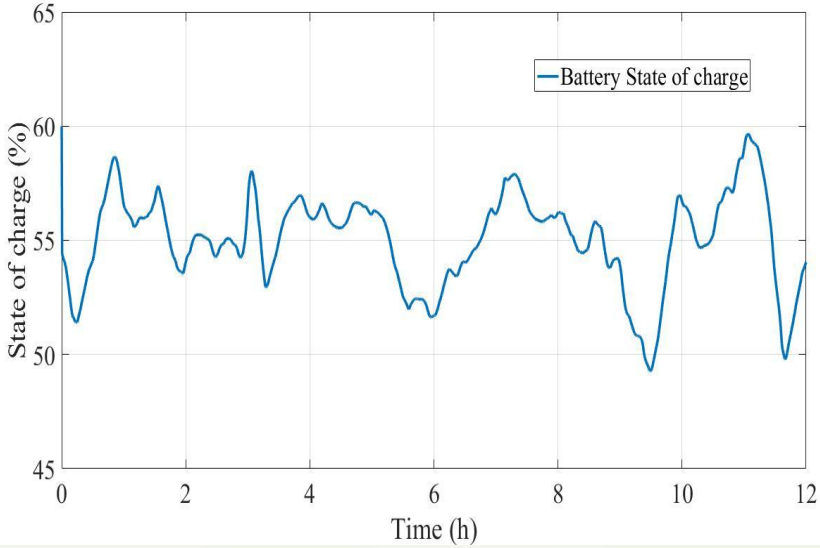
Simulation results

1 BESS system



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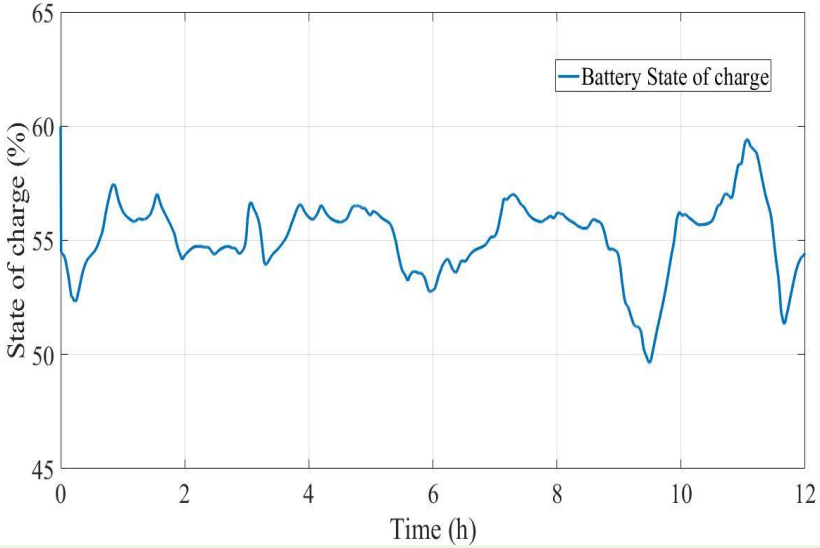
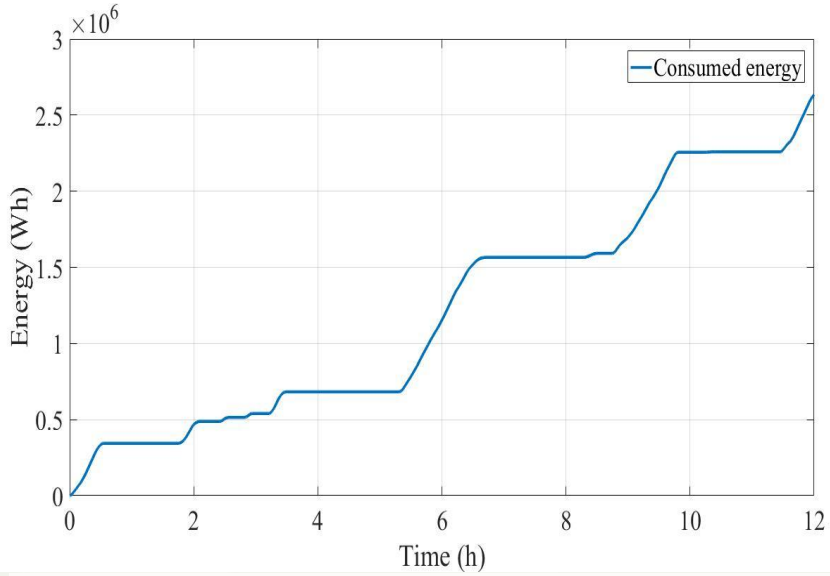


✓ Reduction of the SoC variation

Simulation results

1 BESS system



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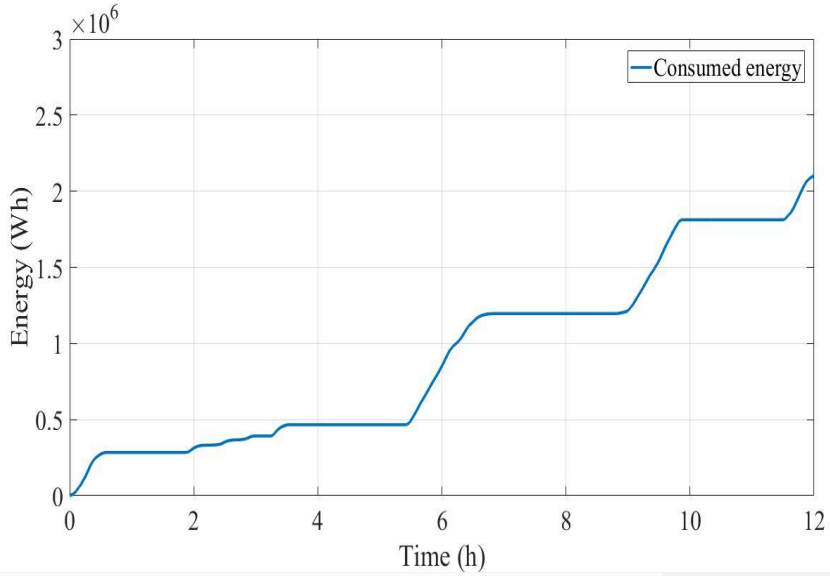


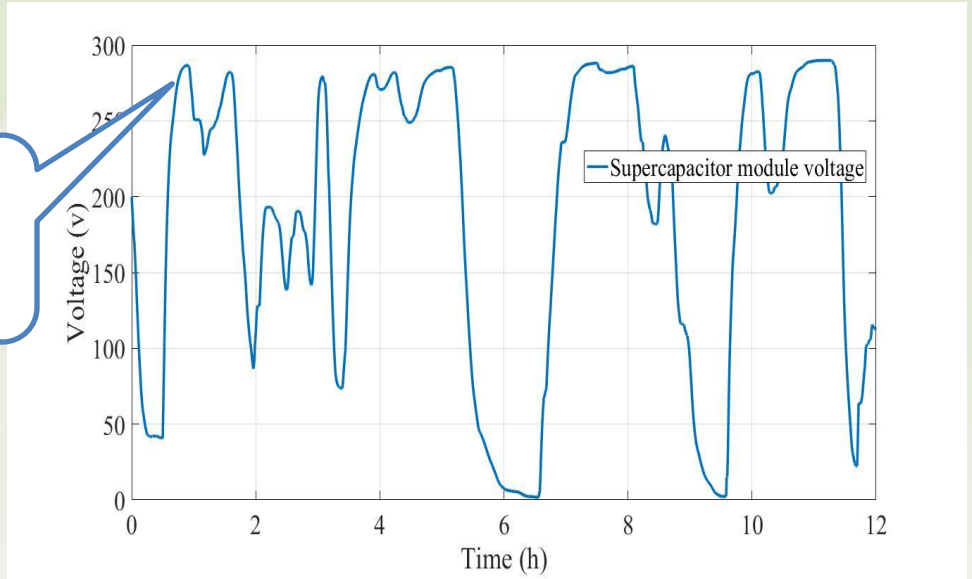
✓ Decrease of the amount of energy used from the grid to control the battery SoC

Simulation results

1 BESS system

2 HESS system p=3%

SC pack is composed of 100 parallel SC units within 2.85v nominal voltage



- ✓ SC voltage is within the operational range
- ✓ Many charge and discharge cycles

- Hybrid Energy System (HESS) are a good candidate for providing grid frequency response.

- HESS allows to reduce the number of the partial cycles of the battery and improve the overall system efficiency

- More control algorithm and configurations should investigated for more efficient implementation of HESS

Thank you
for your attention