Modelling, control and integration of energy storage systems

Ramon Costa-Castelló
ramon.costa@upc.edu

Institut de Robòtica i Informàtica Industrial (CSIC-UPC)
Depart. d'Enginyeria de Sistemes, Automàtica i Informàtica Industrial (ESAII)
Escola Tècnica Superior d'Enginyeria Industrial de Barcelona (ESTSEIB)
Universitat Politècnica de Catalunya (UPC)

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Presentation Outline

- Where do I come from ?
- The Role of energy storage system
- Redox Flow Batteries

Where do I come from ?

- Among the world's 50 best universities in Engineering in the QS and Shanghai rankings by subject.
- 30,864 students

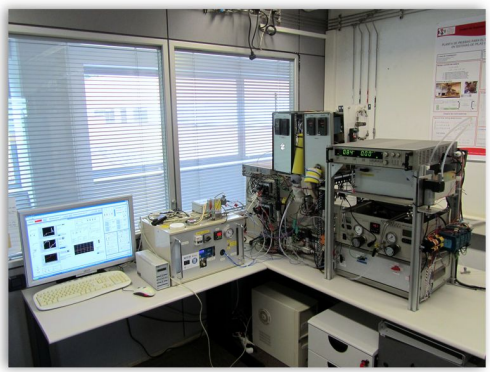
Where do I come from ?

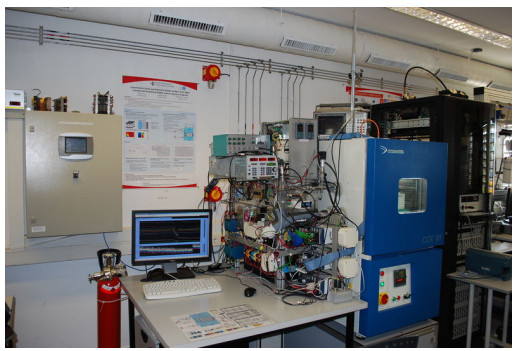
IRI Automatic Control Group

- Modeling and Control Sytem Design
- State and parameter estimation
- Fault diagnosis & Fault-tolerant control
- Prognosis and system health monitoring
- Advanced control of complex and large-scale systems

Where do I come from ?

Hydrogen and energy laboratory





- Modeling and control of electrochemical systems
- Hydrogen Technologies (mobility, CHP)
- Redox Flow Bateries.

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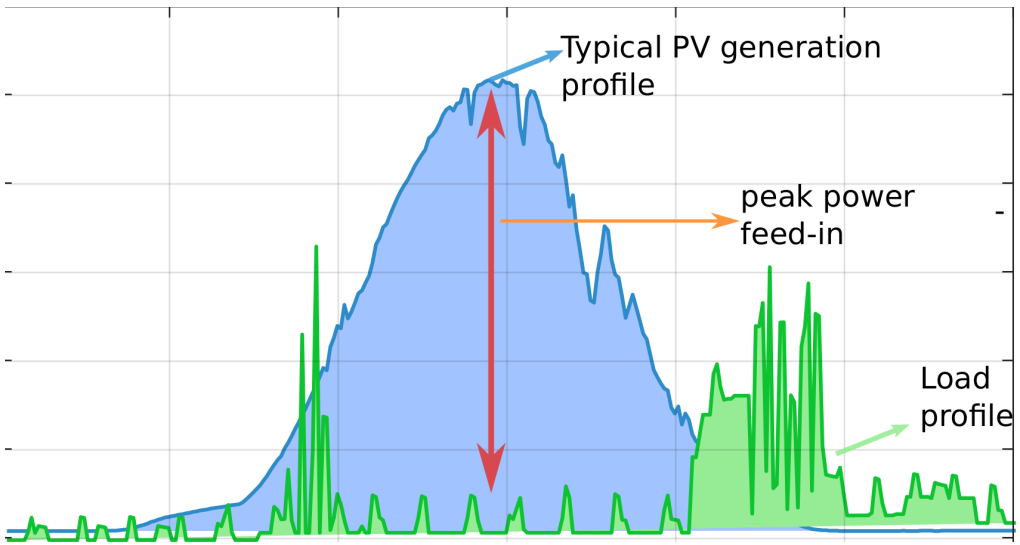
Impact of RES integration on electrical grids



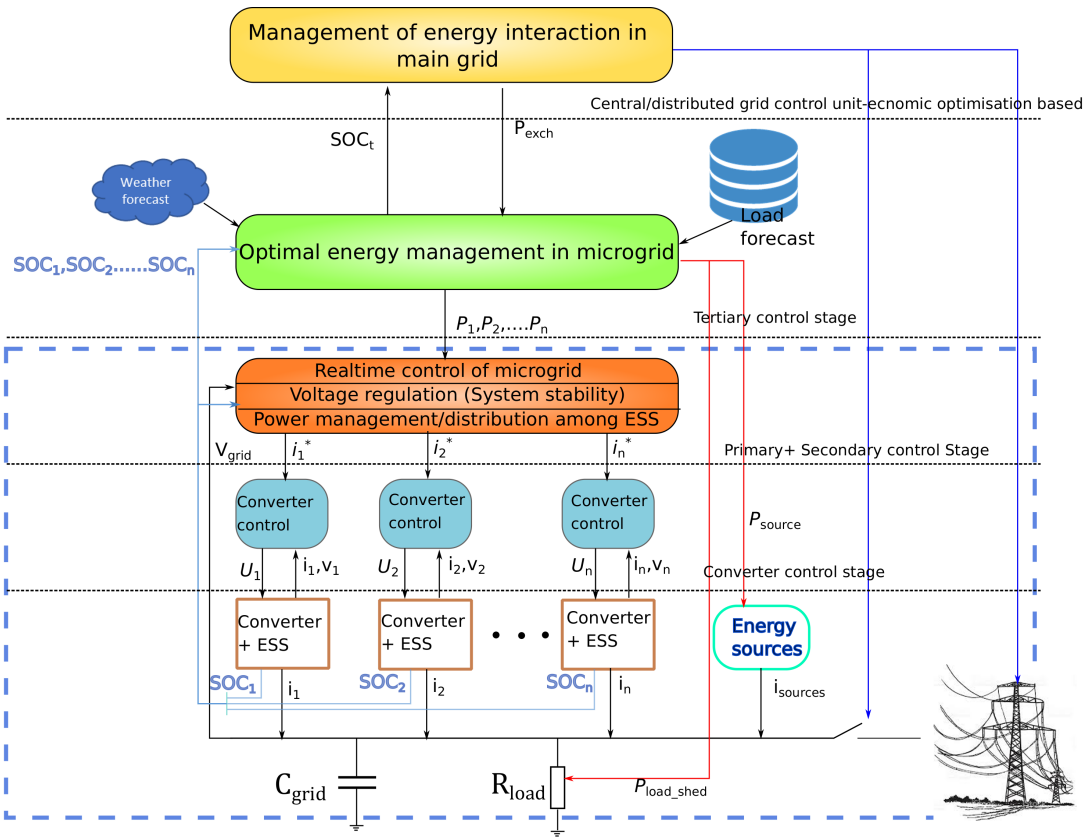
- RES are non dispatchable, intermittent and load decoupled in generation
  - Grid congestion, Voltage regulation, Stability issues from power imbalance
- Weakening of grid by replacing resilient generating systems with static RES

→ Energy storage systems used to mitigate issues with RES integration!!!

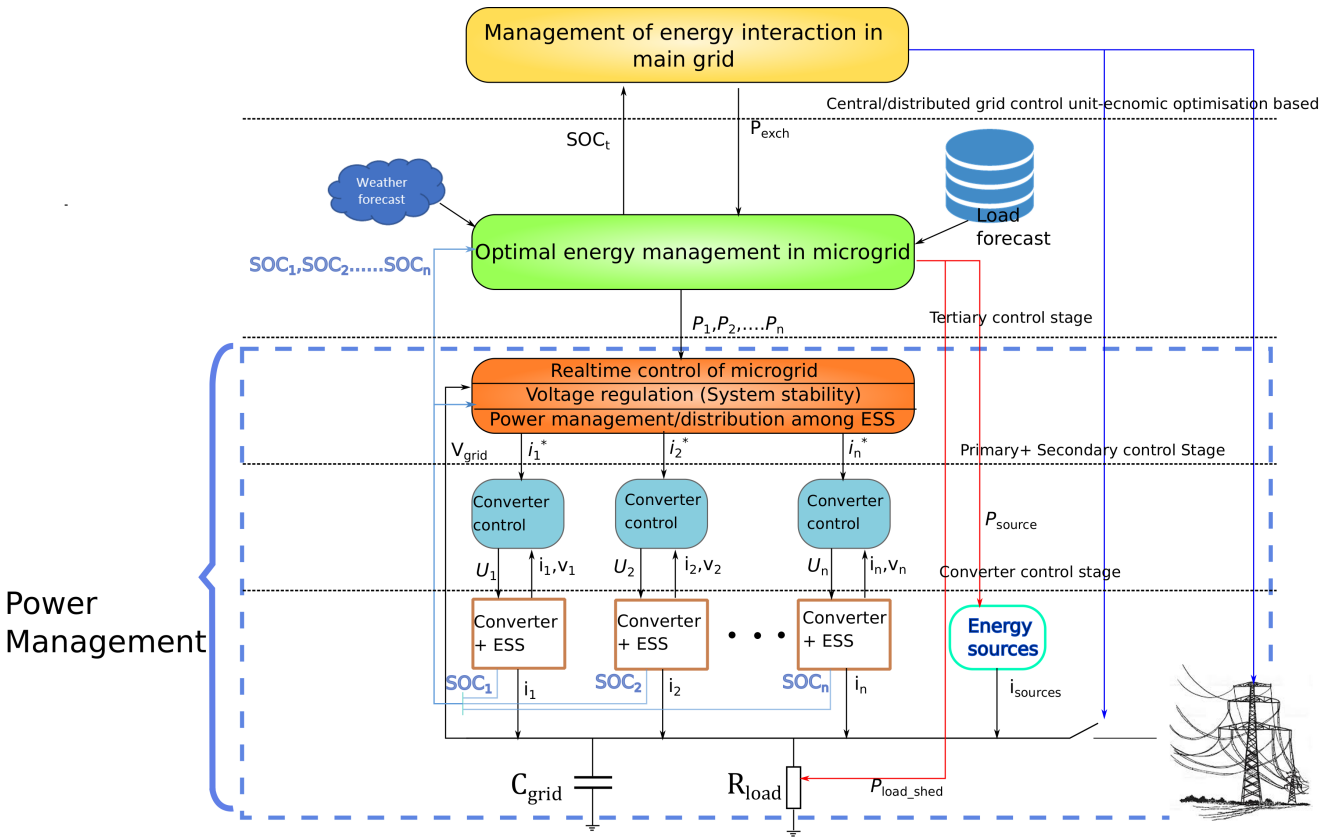
The role of automatic control in ESS

- ESS technology
  - Readiness (i.e SOC and SOH estimation)
  - Help to improve efficiency and lifetime.
- Grid interfacing power converter systems
  - Real-time control of ESS for improved grid resilience, power quality and stability.
- Management of ESS
  - Optimising operation of ESS and electric grids.
  - Minimise component degradation and improved lifetime.

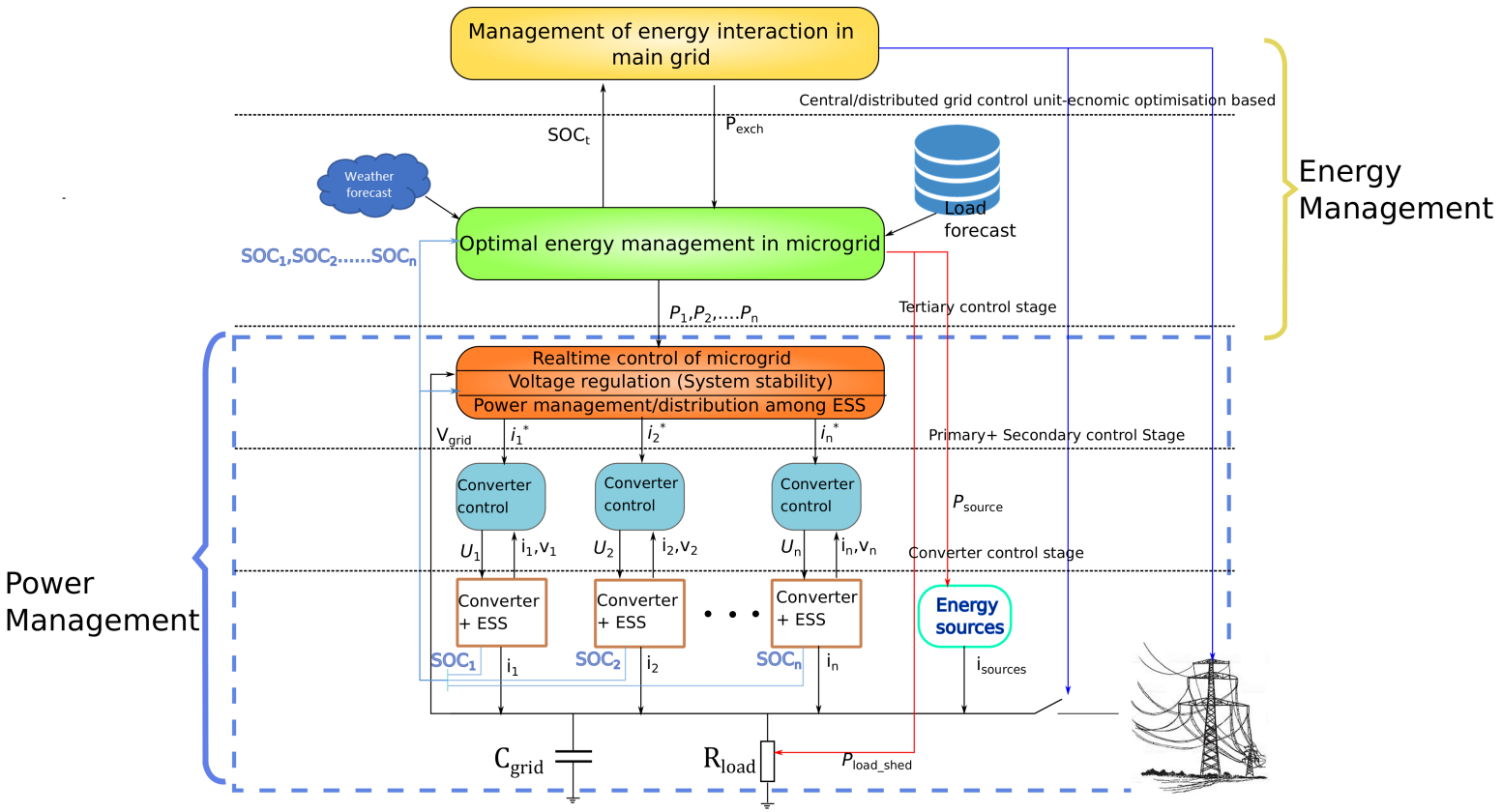
Control architecture for ESS in microgrids



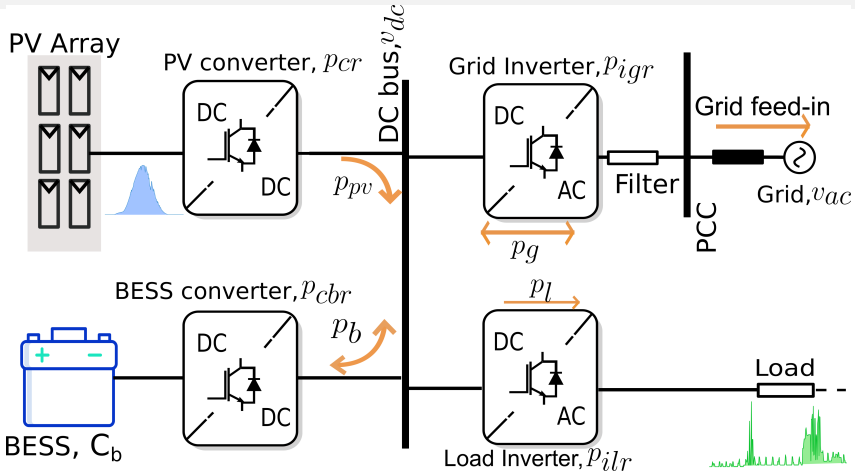
Control architecture for ESS in microgrids

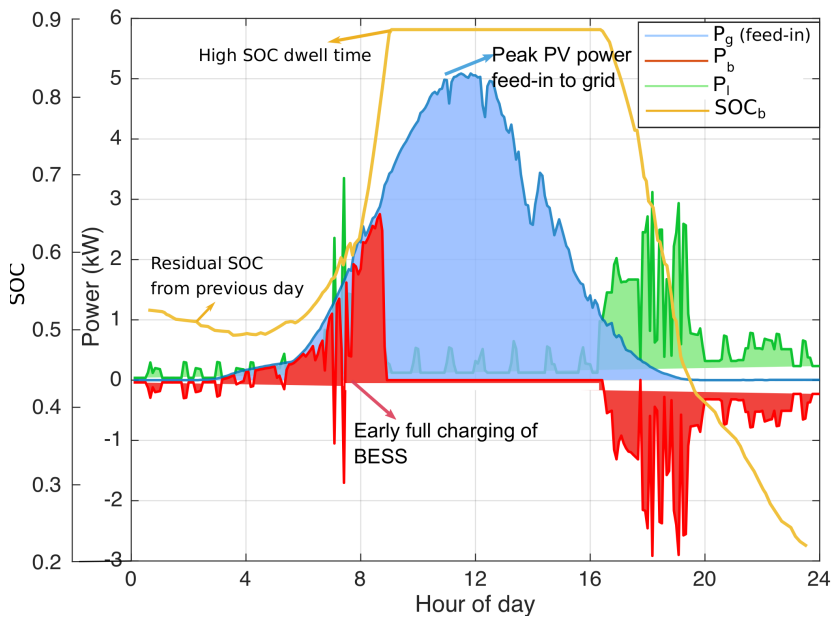


Control architecture for ESS in microgrids



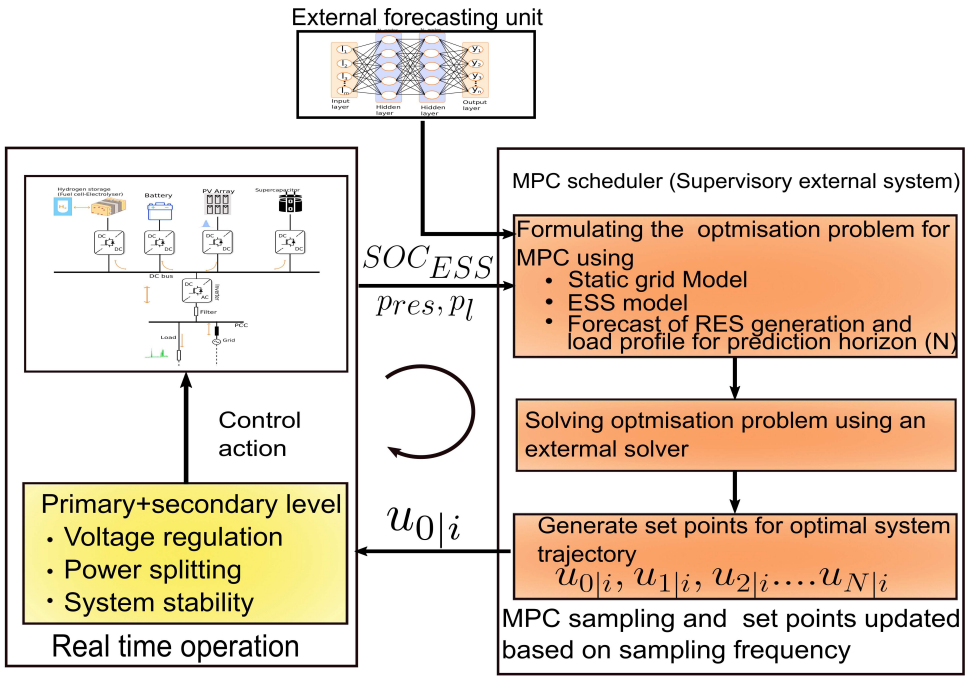
MPC for grid connected systems





- Conventional control: maximising self-consumption for economic benefit
  - Grid congestion
  - Battery degradation
- MPC with forecast information can overcome this
- How does forecast accuracy affect MPC performance??

Model predictive control

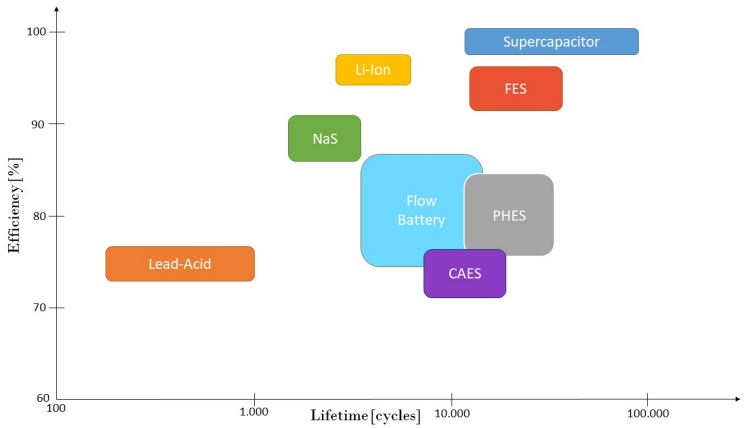


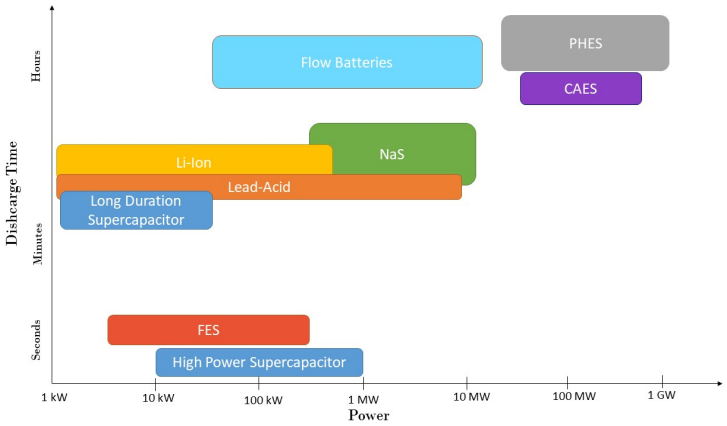
Existing works in MPC for electrical system has only focussed on

- Improving operational efficiency
- Achieve economic operation: *energy arbitrage*, *reduce operational costs*.

Different ESS

Different ESS offer different possibilities and characteristics:

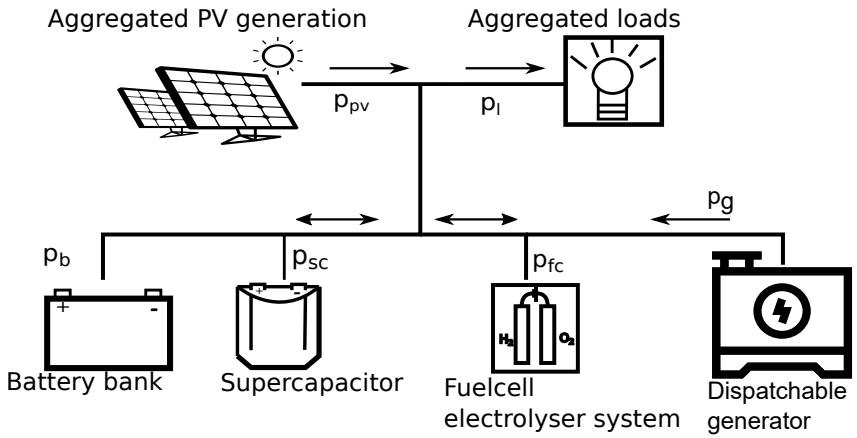




We have experience using :

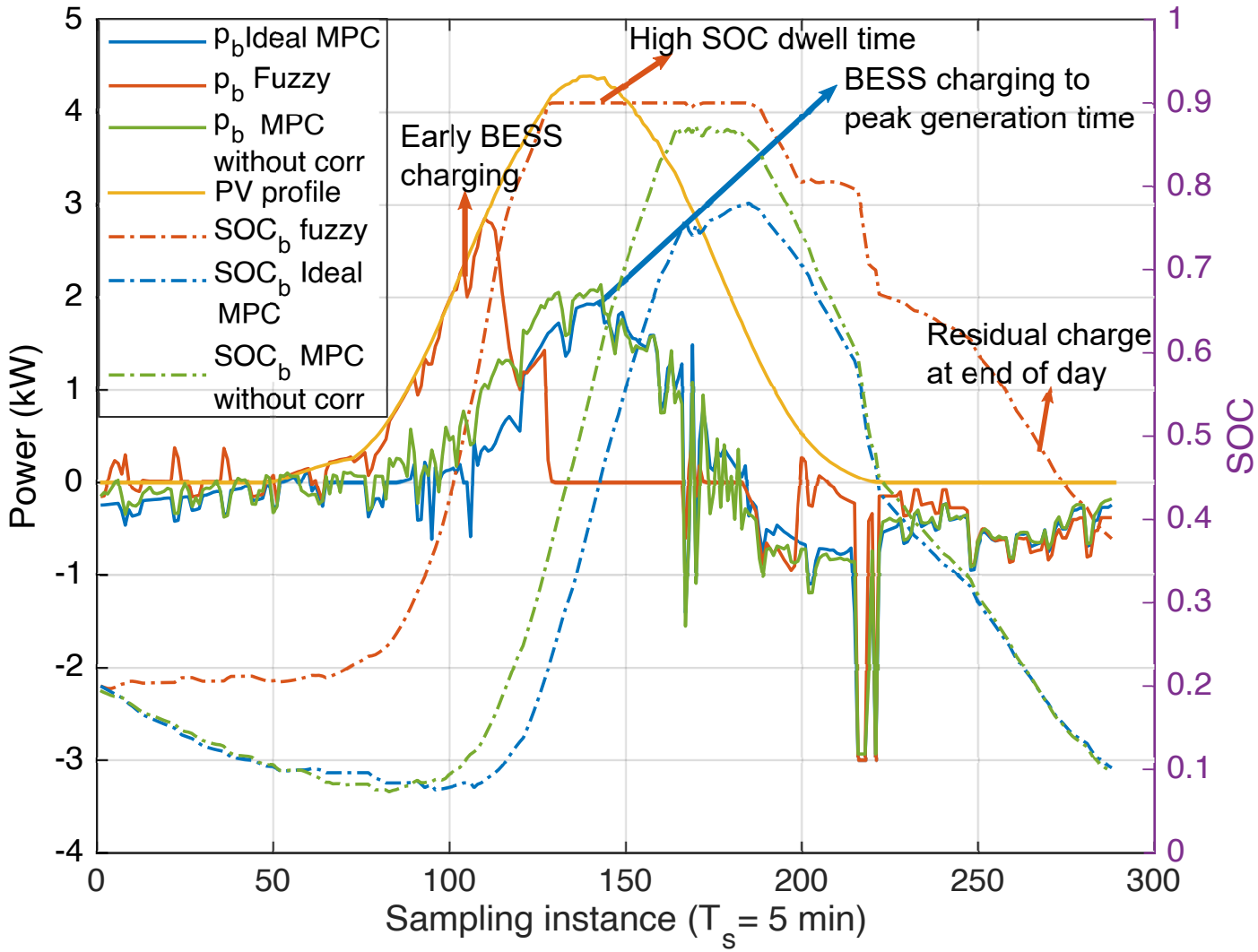
- Supercapacitor
- Batteries (LIPEFO)
- Hydrogen
- Vanadium Redox Flow Batteries (VRFB)

MPC for islanded microgrids with hybrid ESS



- Tri-hybrid ESS needed to ensure maximum utilisation of RES energy
- Lack of infinite reservoir in main grid
- Need for power curtailment and dispatchable generation
- MPC can be used to achieve maximisation of RES generation utilisation, minimisation of ESS degradation and maximisation of microgrid operational efficiency

Results- energy management in islanded grid



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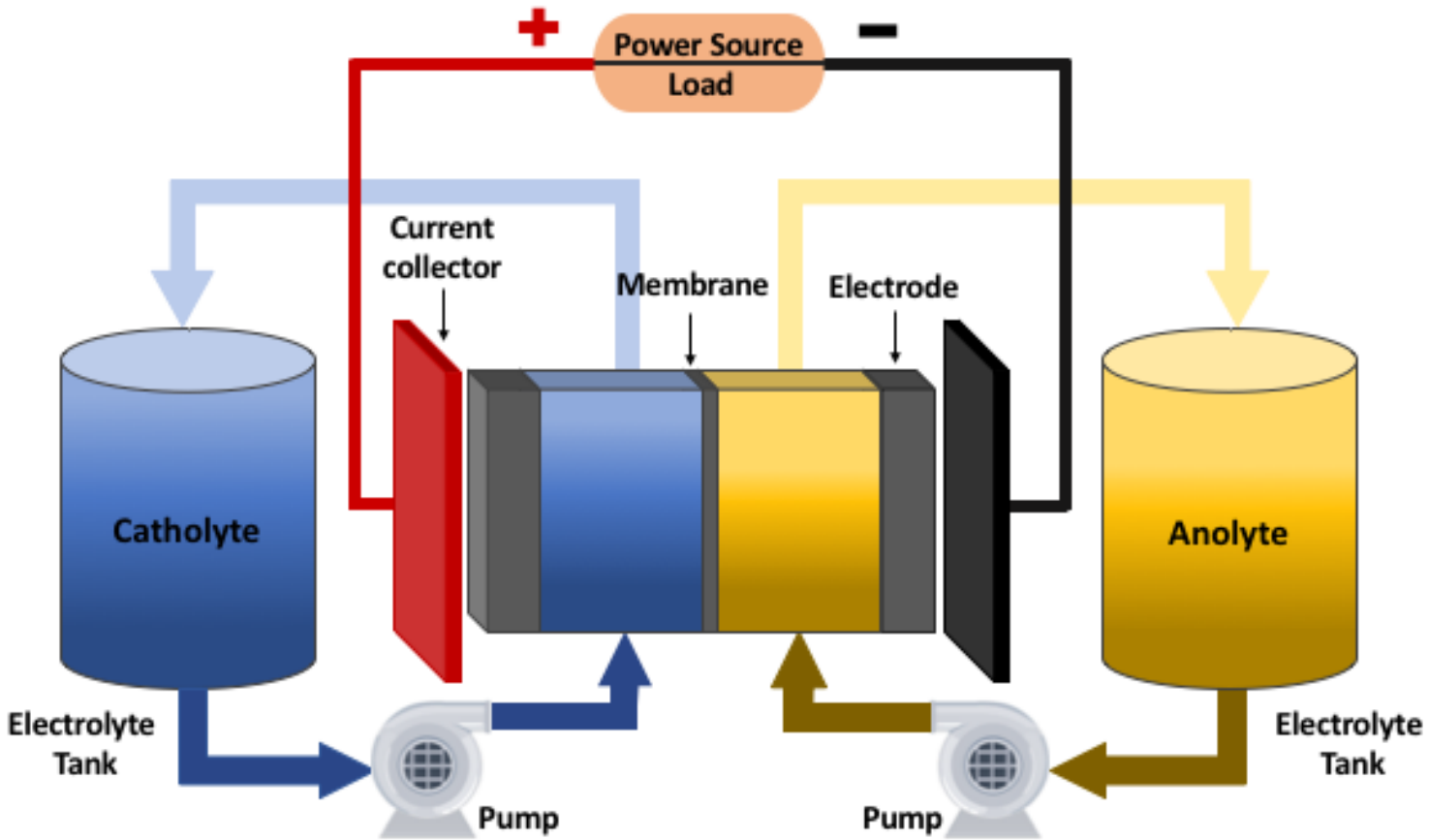
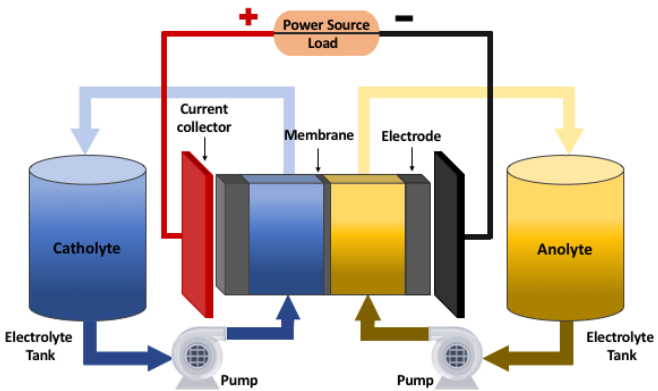
Redox Flow Batteries



Redox Flow Batteries : Working topics



- SOC/SOH estimation based on electrochemical models
- Online/Offline parameter estimation from experimental data
- Optimal operation modes (determining optimal electrolyte flow)
- Simplified models to integrate RFB in electrical networks

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Recent Publications

- Nonlinear Adaptive Observation of the Liquid Water Saturation in Polymer Electrolyte Membrane Fuel Cells. A.Cecilia, M Serra, R. Costa-Castelló. Journal of Power Sources. DOI: 10.1016/j.jpowsour.2021.229641.
- An analysis of multi objective energy scheduling in PV-BESS system under prediction uncertainty U. R. Nair, M. Sandelic, A. Sangwongwanich, T. Dragicevic, R. Costa-Castelló, and F. Blaabjerg. IEEE Transactions on Energy Conversion, 2021. DOI: 10.1109/TEC.2021.3055453.
- Grid congestion mitigation and battery degradation minimisation using model predictive control in PV-based microgrid U. R. Nair, M. Sandelic, A. Sangwongwanich, T. Dragicevic, R. Costa-Castelló, and F. Blaabjerg, IEEE Transactions on Energy Conversion, 2021. DOI: 10.1109/TEC.2020.3032534.
- Redox flow batteries: A literature review oriented to automatic control. A. Clemente and Ramon Costa-Castelló. Energies, vol. 13, no. 17, 2020. DOI: 10.3390/en13174514
- Real-time Adaptive Parameter Estimation for a Polymer Electrolyte Membrane Fuel Cell. Y. Xing, J. Na, R.Costa-Castello. IEEE Transactions on Industrial Informatics. DOI 10.1109/TII.2019.2915569

Feel free to contact me :

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Thank you for your attention!

Questions?