Control and management of storage elements in micro-grids

IRP2.2

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under Marie Sklodowska-Curie grant agreement No 675318

Myself

Education:

- Bachelors in electrical and electronics from College of Engineering Trivandrum, India
- Masters in power electronics and drives from Aalborg University, Denmark
- Currently PhD candidate at UPC from January 2017

Professional

- Operations officer at Indian Oil corporation
- Research assistant at Aalborg University

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- Overview of storage systems
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Motivation

Energy directive put forward by countries to cap greenhouse emissions

- EU Energy directive 2020: 20% renewable energy target by 2020
- EU energy policy 2050: 85-90% reduction in greenhouse emissions
  - Vital to reduce global temperature rise by 2 deg C
  - Require 100% electric generation from renewables

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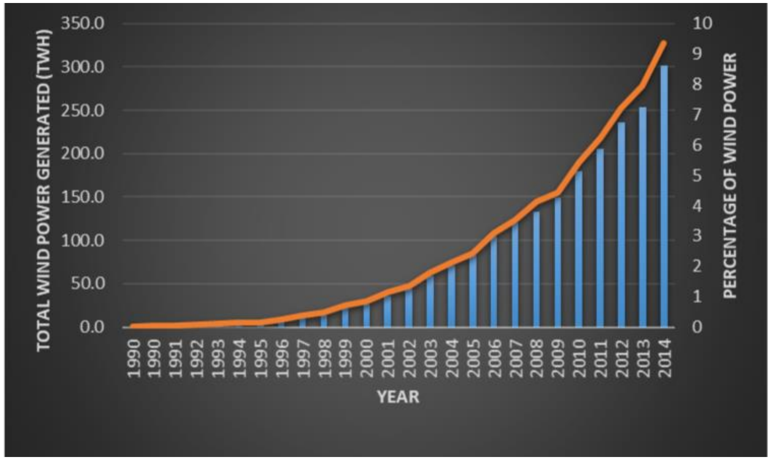
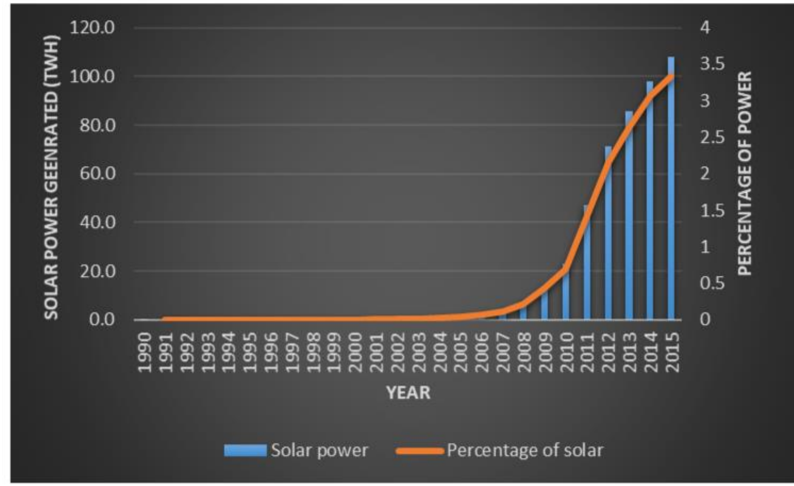
Motivation





Dispatchable source

- Supply response

High inertia systems

Centralised generation

Nondispatchable source

- Demand response

Reduced system inertia

Distributed generation

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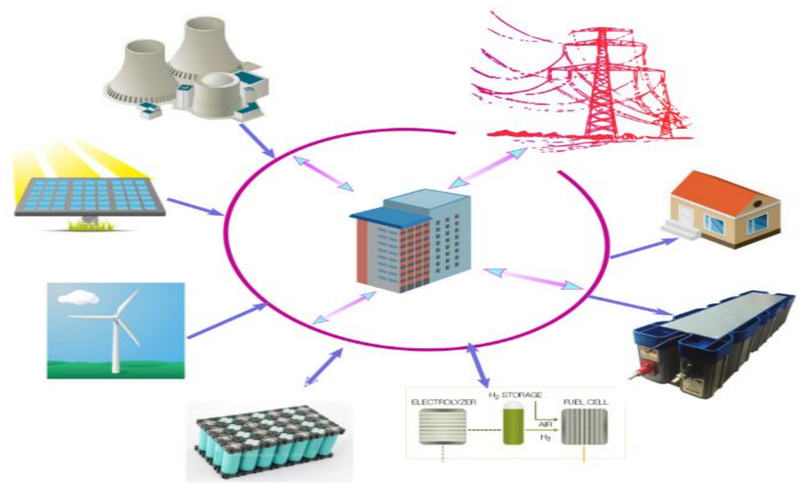
Motivation

Electrical energy storage as a tool for increased penetration of renewable sources by attaining:

- Demand response capability functionality
- Energy security
- Stiffer grids
- Power quality improvement



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Project plan

Objective – integration of hybrid storage system in the microgrid with emphasis on efficient , reliable operation

Project plan

Implement a three level control architecture for a hybrid storage based microgrid with contributions in

- Primary level (converter control)
- Secondary level (energy management among the storages)
- Tertiary level (economic optimisation)

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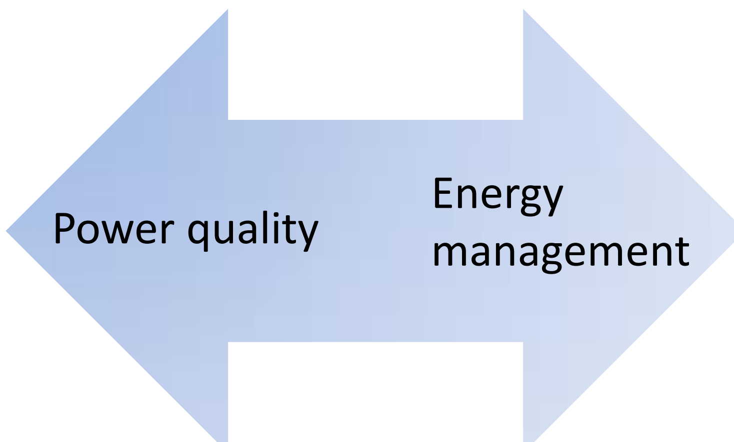
Overview of electrical storage systems

Classification of different electrical storage systems(ESS)

- Supercapacitors
- Flywheels
- Batteries
- Superconducting magnetic storage



- Regenerative fuel cell
- Pumped hydro storage
- Compressed air storage
- Large scale battery
- Thermal energy storage

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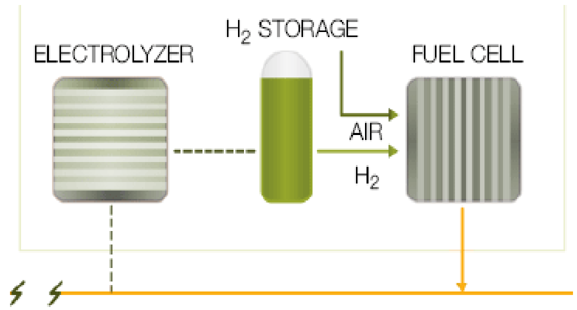
Overview of electrical storage systems

Regenerative FC



Features:

- Very high energy density
- Lifetime of more than 20000 hours for stationary application
- Can be subjected only to low rate of change of load due to accelerated degradation
- Low round trip efficiency(30-40%)
- Very low self discharge

Batteries

Features:

- High energy density
- Lifetime in the range of 10000 cycles
- Can be subjected to higher rate of change in output than FC
- High round trip efficiency of close to 90%
- Very low self discharge

Supercapacitor

Features:

- High power density
- Lifetime of more than 1,00,000 cycles
- Very high rate of change of power output deliverability
- High round trip efficiency of 90%
- Significant self discharge

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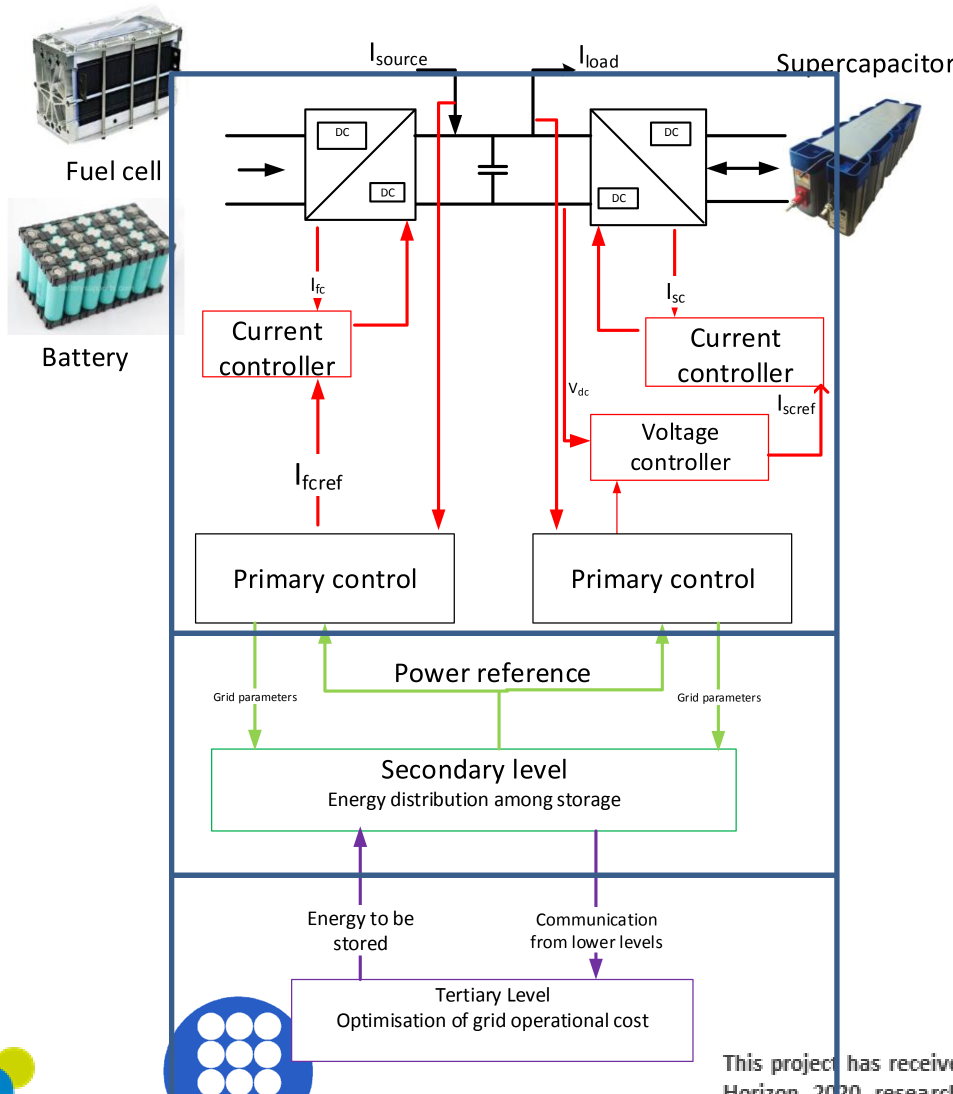
Control architecture



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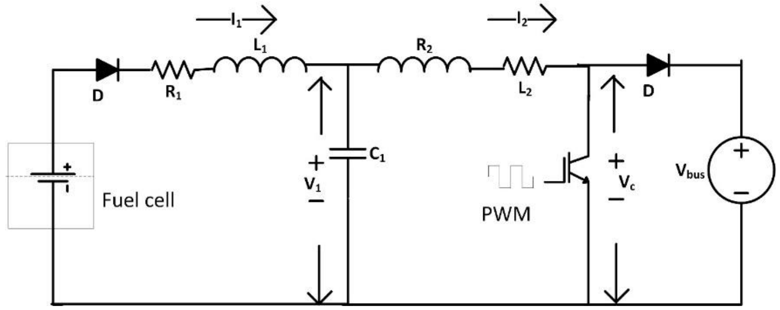
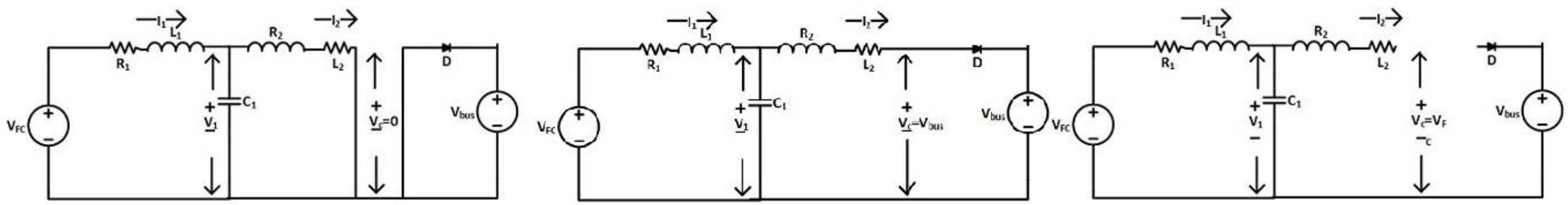
Power converter units

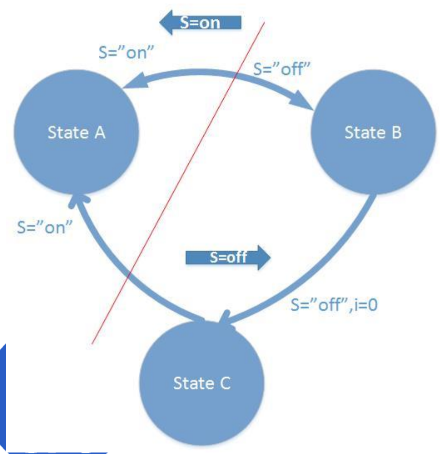




State A
(a)

State B
(b)

State C
(c)



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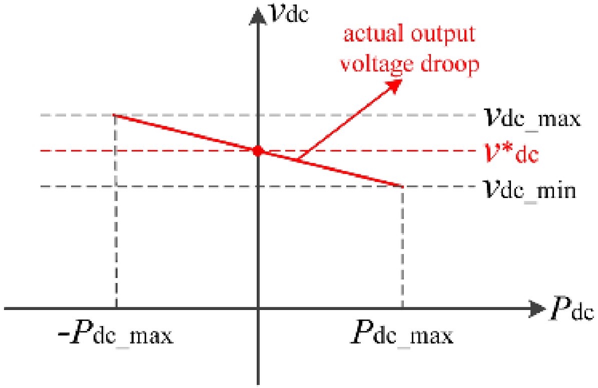
Primary level control

Summary of observations from literature survey

Control method for converters at the primary level:

- Droop control employed for current sharing of parallel connected converters
  - Voltage scheduling
  - Gain scheduling
- In storage systems
  - Frequency based splitting
  - SOC based droop control



Controllers used for the primary (converter) control

- Classic PI controllers
- Sliding mode controllers, H-infinity etc…

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Primary level control

Hybrid system:

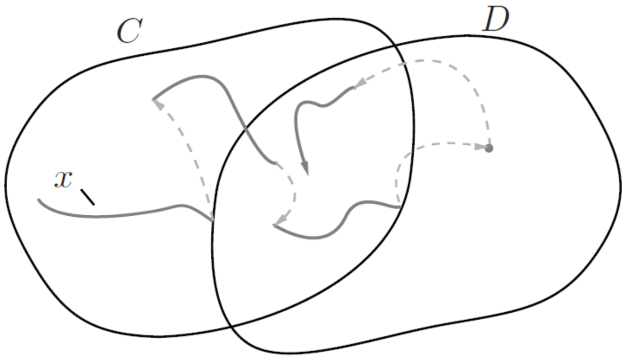
Modelling [1]

$$Fc(x) = \begin{cases} F(x) & if \;\; x \in C \\ \emptyset & if \;\; x \notin C \end{cases}$$

$$Gc(x) = \begin{cases} G(x) & if \; x \in D \\ \emptyset & if \;\; x \notin D \end{cases}$$

C is the flow set, F is the flow map

D is the jump set, G is the jump map



[1] R. Goebel, R. G. Sanfelice, and A. R. Teel, Hybrid Dynamical Systems : Modeling, Stability, and Robustness. Princeton University Press, 2012.

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Primary level control

Reset controller (PI+CI)

- PI controller used along with Clegg integrator (CI) introducing non linearity
- Reset action achieved through a defined resetting law

Motivation:

- Easy implementation
- Possibility of obtaining simple design equations allowing plug and play capability
- Possibility of obtaining flat response which allows fast response of converters and voltage restorations smoothly
- Allows easy integration with the established droop control

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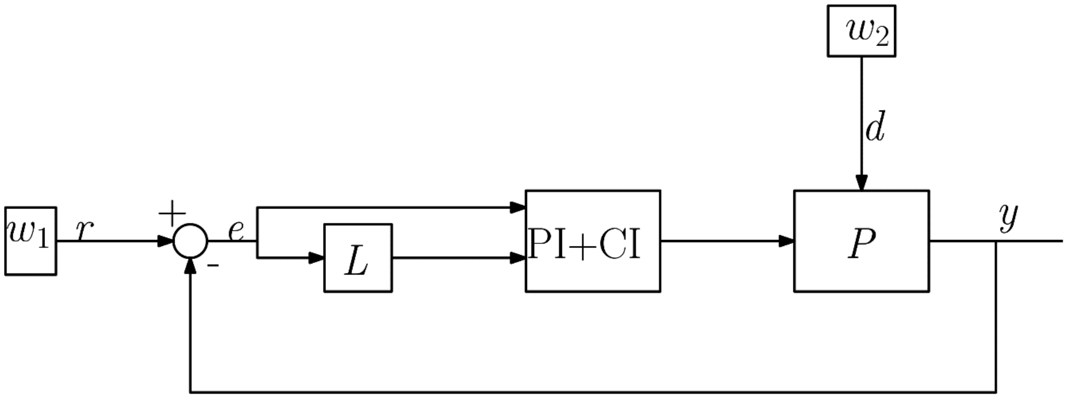
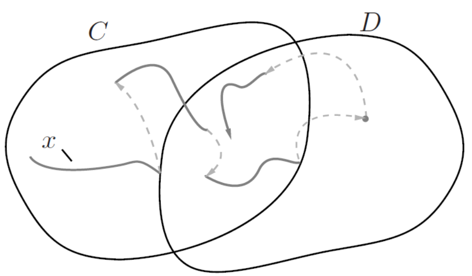
Primary level control





$$P_{reset}\begin{cases} \dot{x}(t) = Ax(t) & x(t) \notin M \\ x(t^{+}) = A_R x(t), & x(t) \in M \\ y(t) = Cx(t) & \end{cases}$$

Design objectives

- Define reset ratio
- Define resetting law to obtain reference tracking and disturbance rejection
- Ascertain the robustness of the controller

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Current and future work

Current work:

- Lab implementation of PI+CI controller for continuous conduction mode
- Extending the framework of PI+CI system to discontinuous mode
- Publications from the proposed PI+CI controller
- Literature survey and project plan

Future work:

- Define the overall primal level control scheme
- Define secondary and tertiary scheme
- Test all the scheme at the experimental setup at IRI at each level and validate
- Project plan submission on Jan 15 ,2018
- Secondments at University of Bologna and EFACEC during next year

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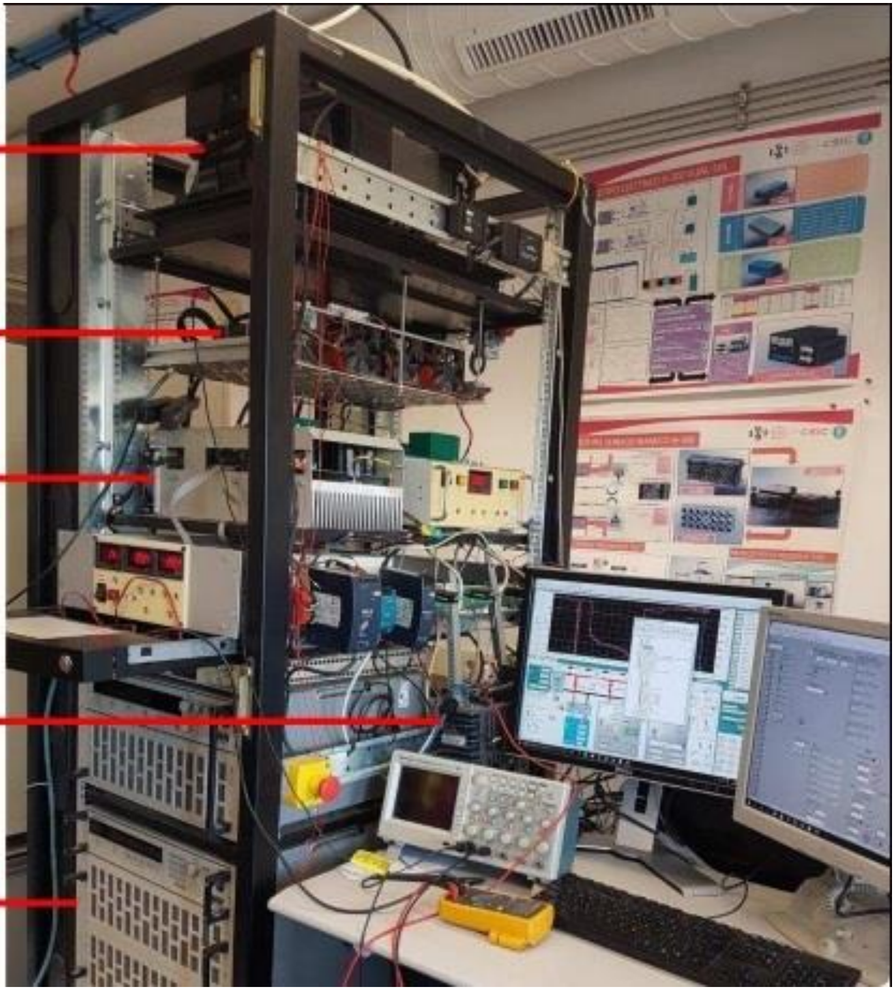
Fuel cell
NEXA™
1200W

Supercapacitor
Maxwell™
165F-48V

Conveter DC-DC
Semikron™
75A-513V

Controller
National Instruments™
Compaq Rio 9035
CPU Dual-Core 1.33 GHz
FPGA Xilinx Kintex-7 7K70T

Source/Sink
H&H GMBH™
3200W



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Thank you!!!

Questions??

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