Control and management of storage elements in micro-grids

IRP2.2

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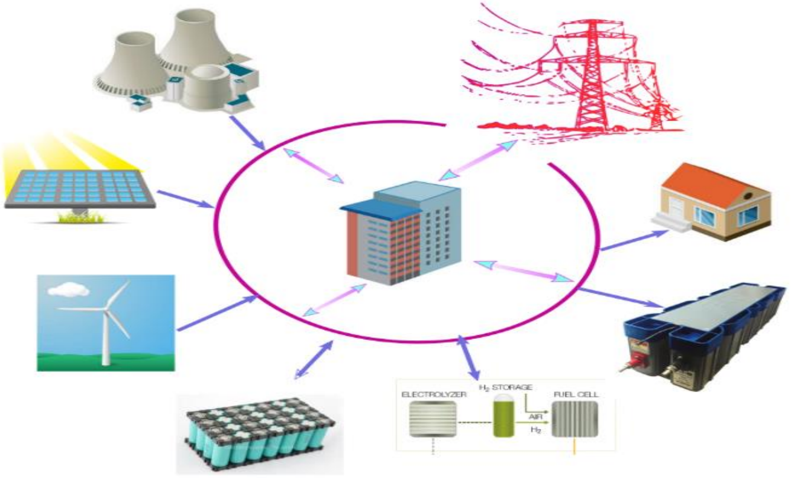
Motivation

Electrical energy storage for increased penetration of renewable sources by ensuring:

- Power balance
- Energy security
- Stiffer grids
- Power quality improvement
- Ride through capability



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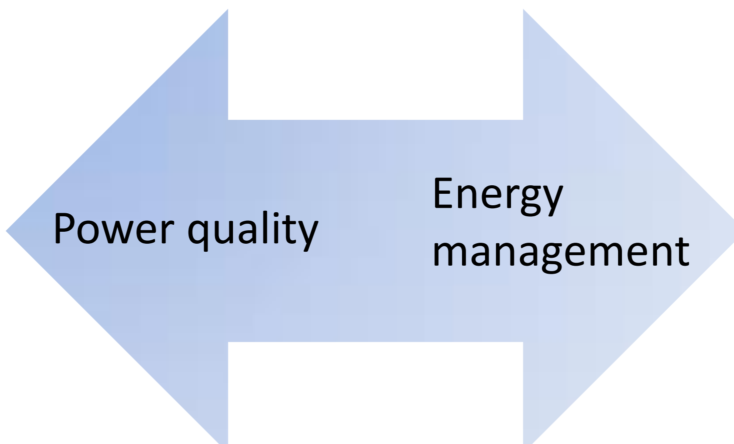
Overview of electrical storage systems

Classification of different electrical storage systems(ESS)

- Supercapacitors
- Flywheels
- Superconducting magnetic storage



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

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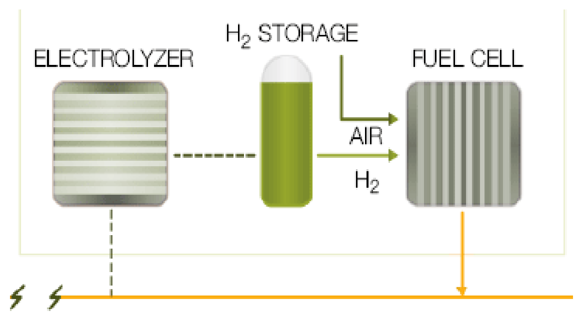
Overview of electrical storage systems

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

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Areas of focus

- *How can the energy be distributed/supplied by the ESS to achieve minimum rate of degradation?*
- *How to effectively consider the stochastic nature of load and generation profiles?*
- *How to effectively integrate multiple microgrids into the grid taking advantage of the functionalities ESS can provide?*

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Thesis objective

Develop and implement a control architecture for an ESS based DC-microgrid which

- *aids the increased penetration of RES at all instances by ensuring an energy balance in the grid*
- *solves an optimum power flow problem for profit maximisation in microgrid by energy interaction with main grid*
- *minimise rate of degradation of ESS through optimal distribution of energy among different ESS.*
- *The proposed control system should be able to achieve all this considering the stochastic nature of the generation and load profiles.*

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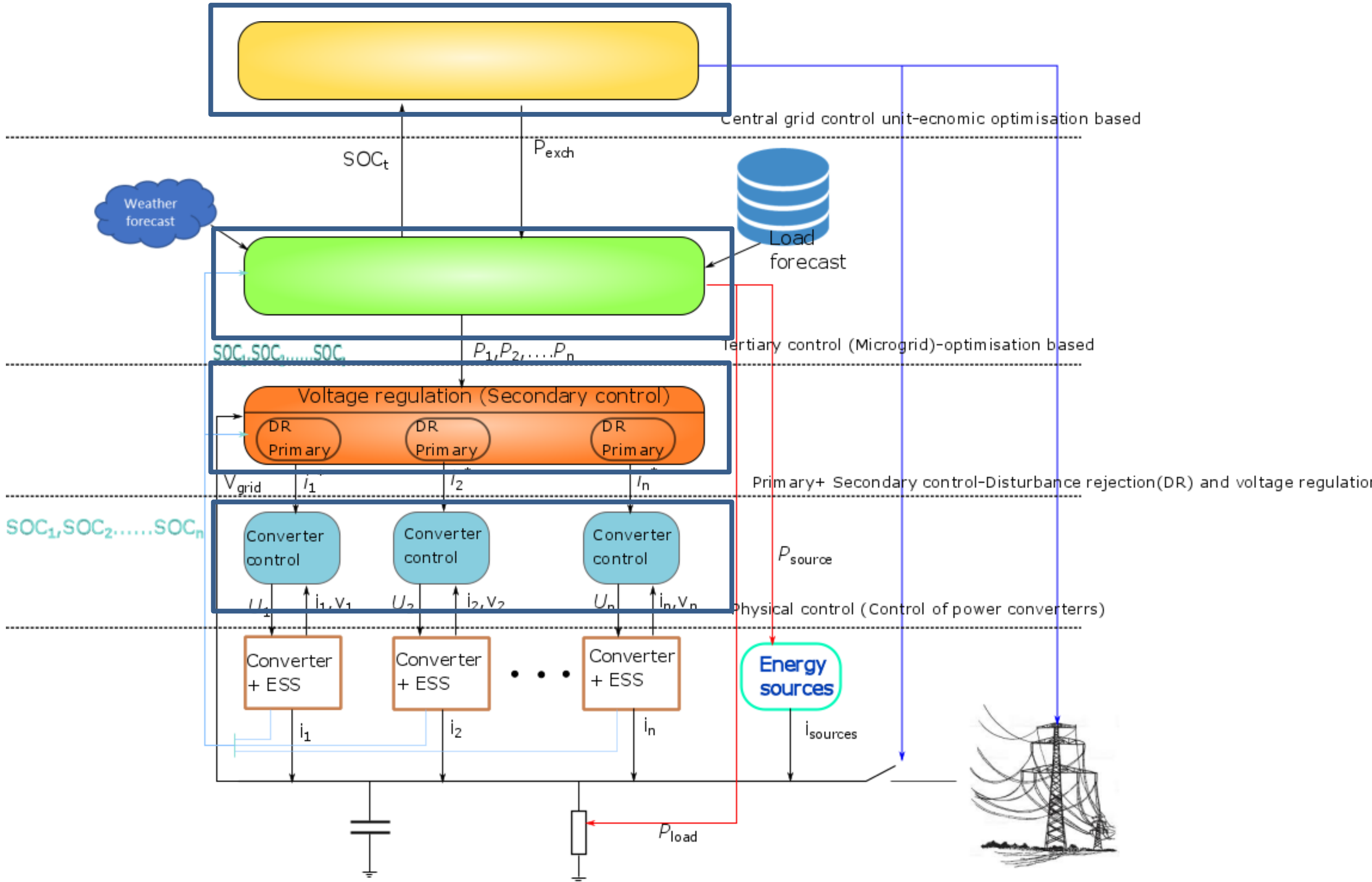
Thesis objective



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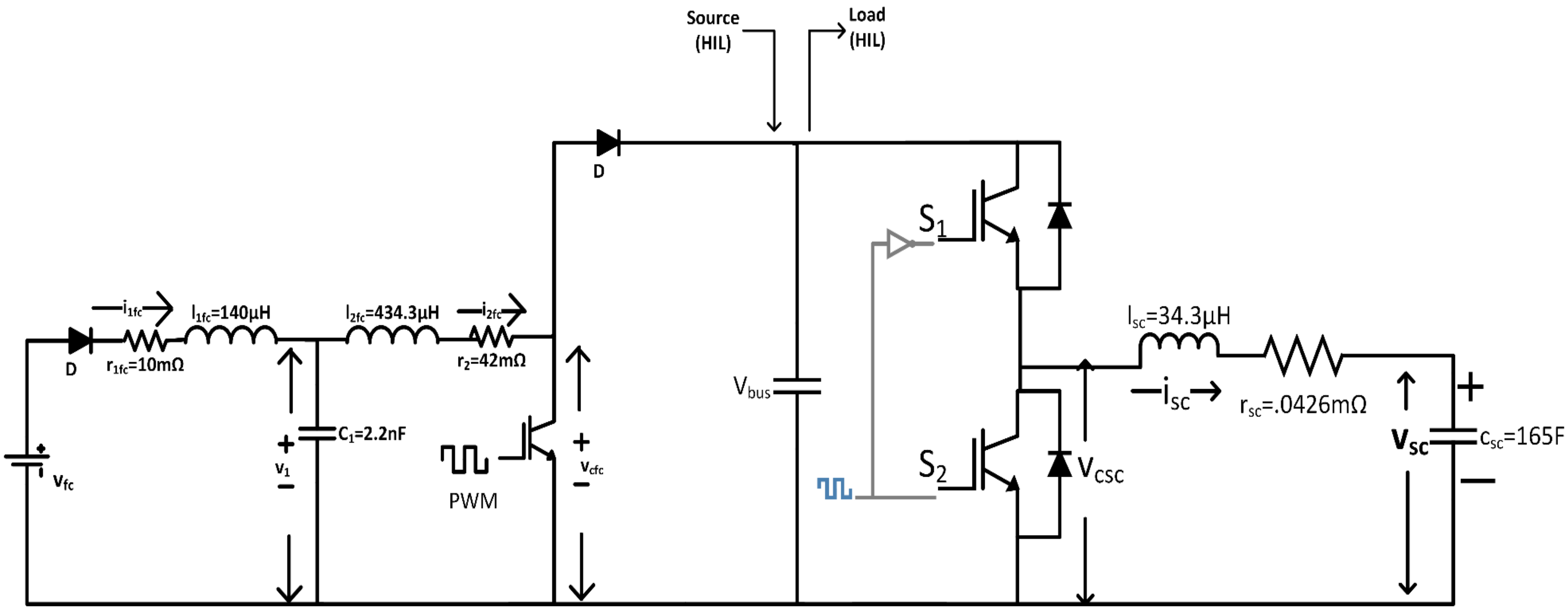
System schematic



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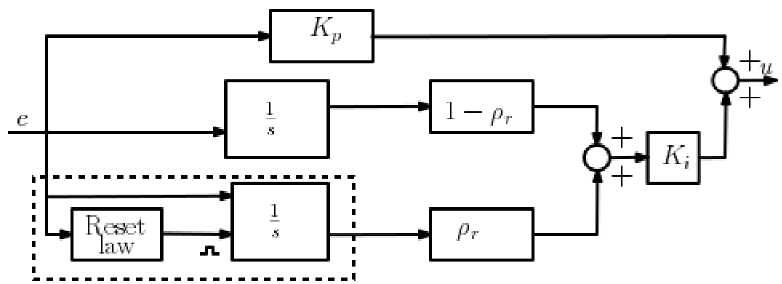
Converter control

PI+CI Reset control



$$PI + CI = \begin{cases} \dot{\rho_{\mathbf{r}}}(\mathbf{t}) = 0, \dot{\mathbf{x}}_{\mathbf{r}}(\mathbf{t}) = \mathbf{A_r x_r(t)} + \mathbf{B_r} e(t), & e(t) \neq 0 \\ \rho_r(t^+) = \mathcal{P}(\mathbf{x_r}, e(t)), \mathbf{x_r}(\mathbf{t^+}) = \mathbf{A}_\rho \mathbf{x_r(t)}, & e(t) = 0 \\ u(t) = \mathbf{C_r}(\rho_{\mathbf{r}}(\mathbf{t}))\mathbf{x_r(t)} + \mathbf{D_r} e(t) \end{cases}$$

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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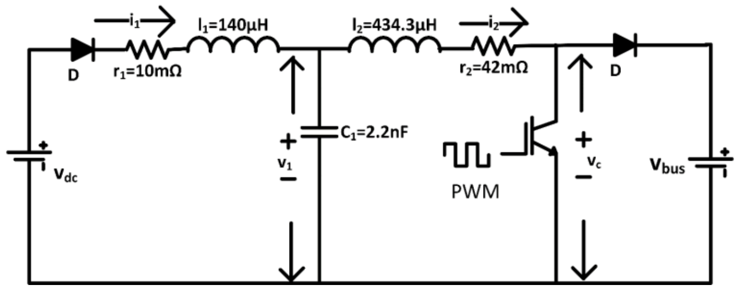
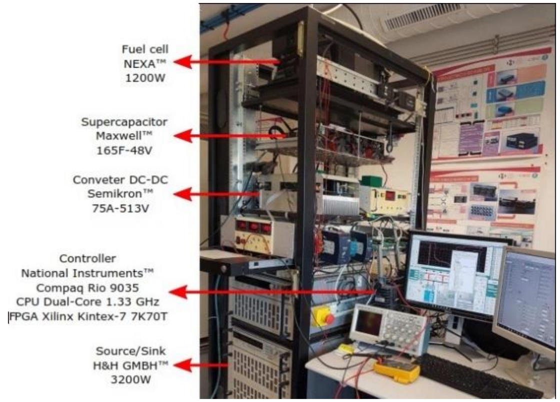
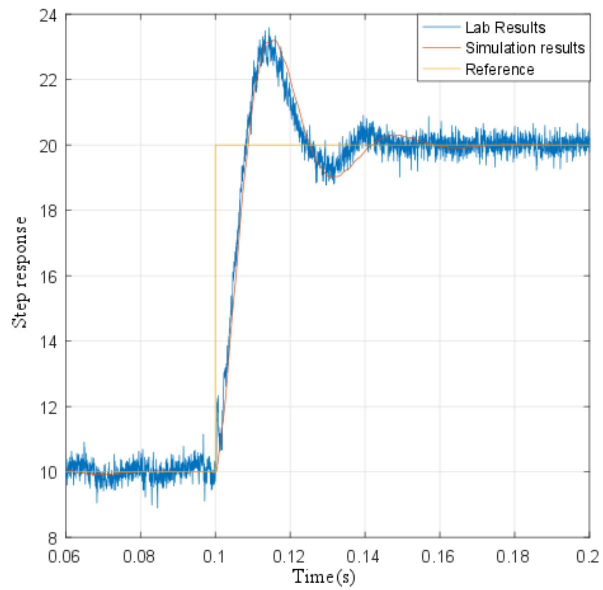
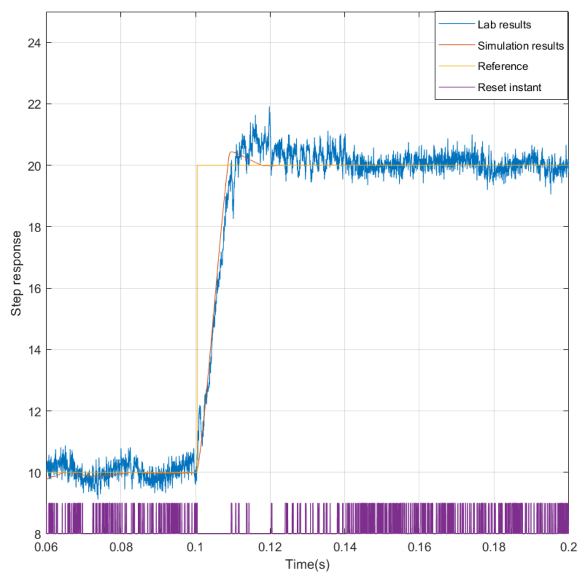
Converter control









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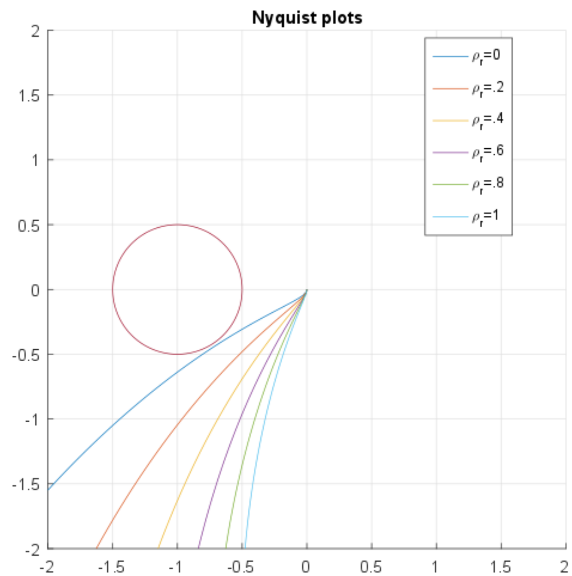
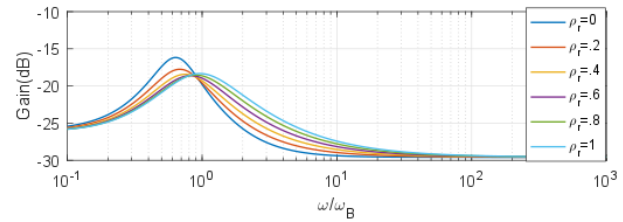
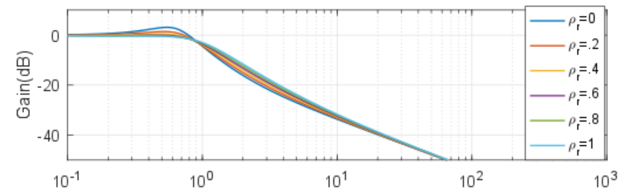
Converter control

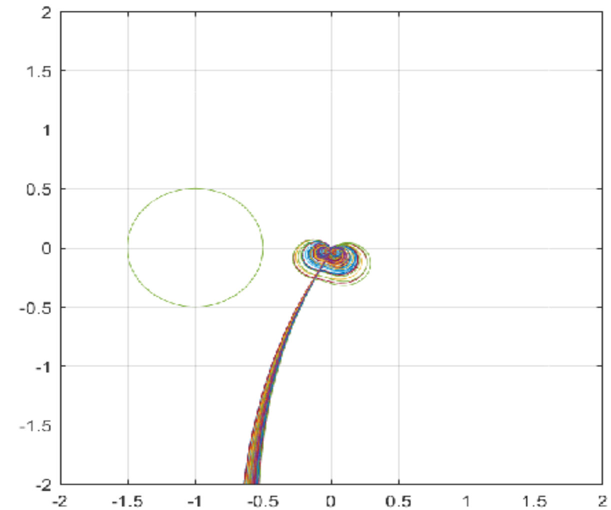
- Describing function of reset controller used for robustness analysis

$$PI + CI(\omega) = k_p \frac{j(\omega\tau_i + \frac{4}{\Pi}\rho_r) + 1}{j\omega\tau_i}$$









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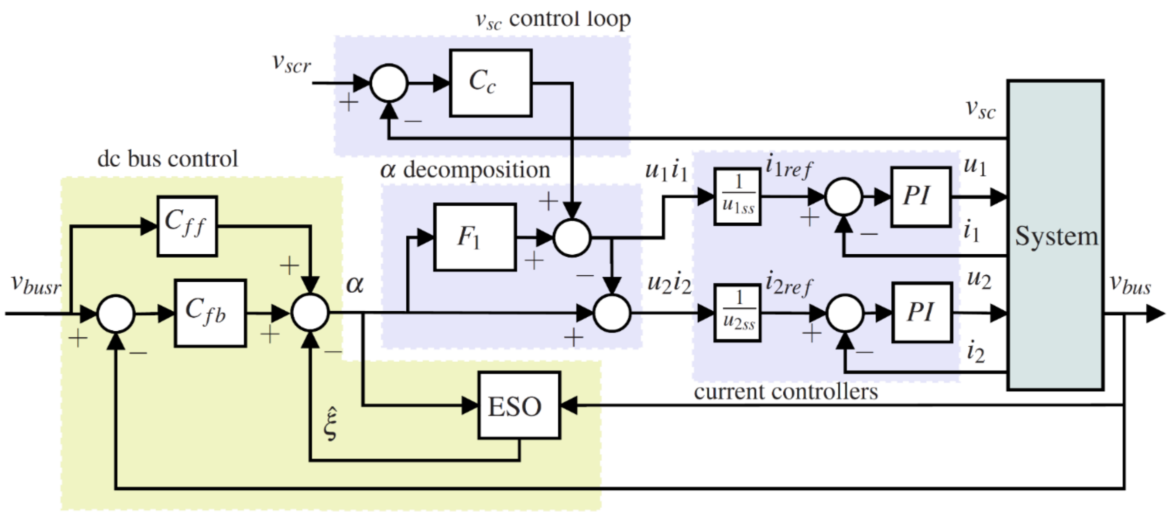
Primary + secondary control

- Developing an adaptive disturbance rejection based control for disturbance rejection and voltage regulation of microgrid.
- Frequency based power splitting for power distribution among ESS



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Current status

- Developed simulations models for the ADRC based control with testing and validation to proceed.
- Expanding the setup to incorporate battery system along with designing of converter and data acquisition systems.
- Presented thesis proposal on February 14,2018.
- Conference paper accepted for the American Control Conference-2018.
- Journal and conference paper under review in Control system technology and PID control conference.
- First secondment in EFACEC, Porto in summer 2018

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