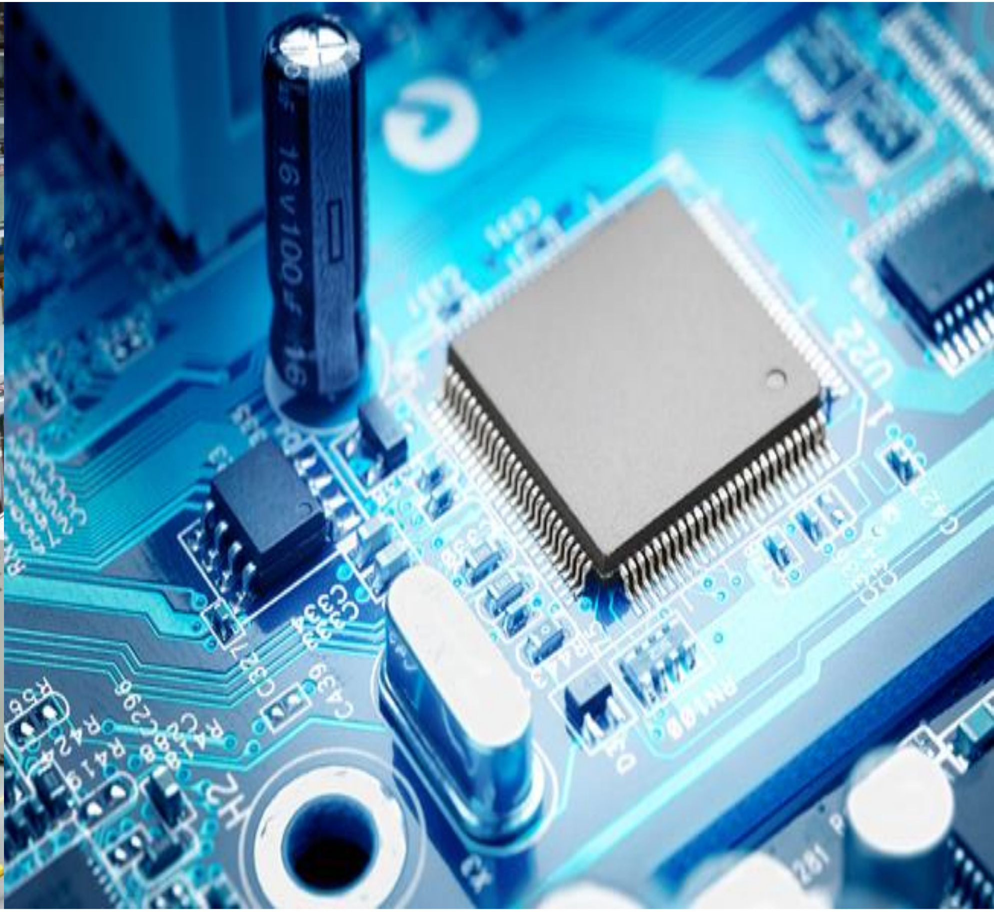

Resilient Hybrid Technology for High-Value Microgrid (RHYTHM) Project

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Incheon Nat'l University, Korea

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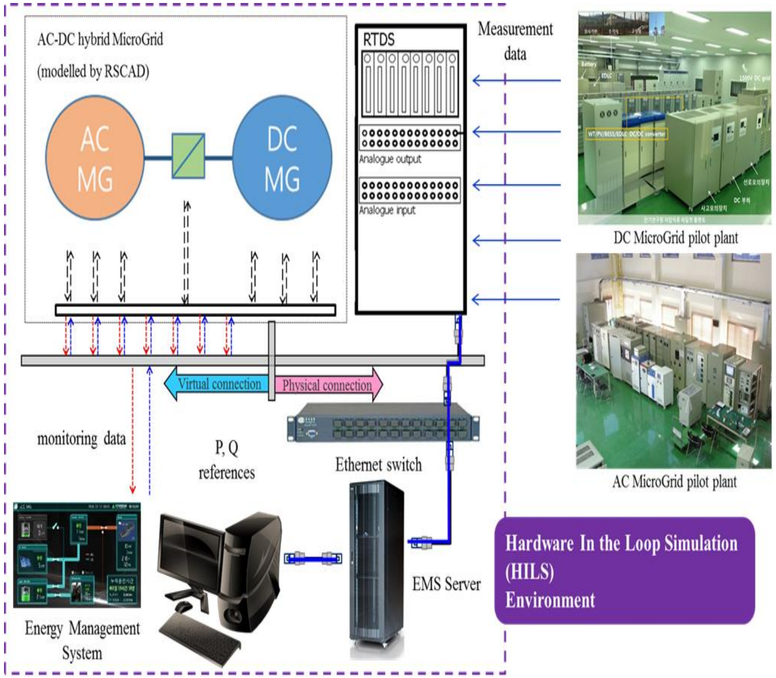
RHYTHM Project Overview

Project Budget
2.2 million USD (Government 1.8M, Private 0.3M)
₤ 998,307 UK (Government)

Project Period
2016.03.01 – 2019.02.28 (3years)

Team
Korea side: 7 Institutes; UK Side: 2 Institutes



Project Goal
Development of strategies for improving the resilience of AC-DC hybrid microgrids

* RHYTHM: Resilient Hybrid Technology for High-value Microgrids

RHYTHM Project Overview

Research Team

Project Head
Incheon Nat'l Univ.
Prof. Hak-Man Kim

Project Head
Imperial College London
Prof. Tim C. Green

Industries: 2, Universities: 4, National Research Institute: 1

Universities: 2

RHYTHM Project Overview

Developed Core Technologies

01 Development of EMS algorithm for resilient operation of hybrid microgrids

02 Design of Interlinking converter considering resiliency of hybrid microgrids

03 Development of control strategy for stability in islanded mode operation

04 Design of reliable and low latency communication system for real-time communication

05 Design of hybrid AC and DC microgrid for improving resiliency and engineering tools

RHYTHM Project Overview

Work Packages and Respective Tasks

Development of strategies for enhancing the resilience of AC-DC hybrid microgrids

WP1 EMS

Development and testing of operation algorithm for resilience enhancement of AC DC hybrid microgrid.

WP2 Interlinking Converter

Development of multi-level converter considering redundancy, real-time communication, fault protection, etc.

WP3 Safety Enhancement Control

Design of control schemes for enhancing safety, seamless control, and stability enhancement during islanded operation.

WP4 Design and Business Model

Optimal design of software tool for analysis and business model proposition along with evaluation.

WP5 Pilot Plant Testing

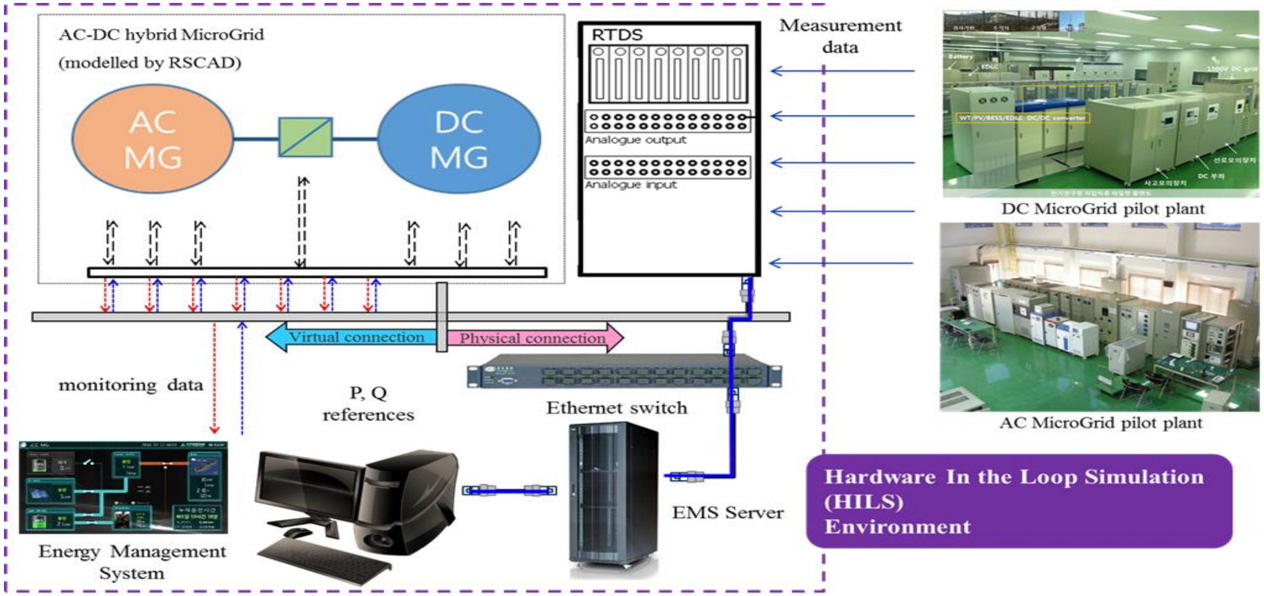
Testing of the developed operation/ control strategies in pilot plant having 200kW AC microgrid and 200kW DC microgrid.

RHYTHM Project Overview

EMS Core Tasks and Testbed

Core Tasks

- To develop resilient EMS algorithm (by Incheon Nat'l Univ.)
- To develop detail BESS model with BEMS model for EMS (by Incheon Nat'l Univ. and Univ. of Oxford)
- To design and develop prototype EMS (by KERI)
- To develop Testbed (by KERI)
- To test performance (by KERI and Incheon Nat'l Univ.)



Configuration

- 100kVA DC MG
- 200kVA AC MG
- 100kVA ILC

Resilient Operation

Challenges and Potential Solutions

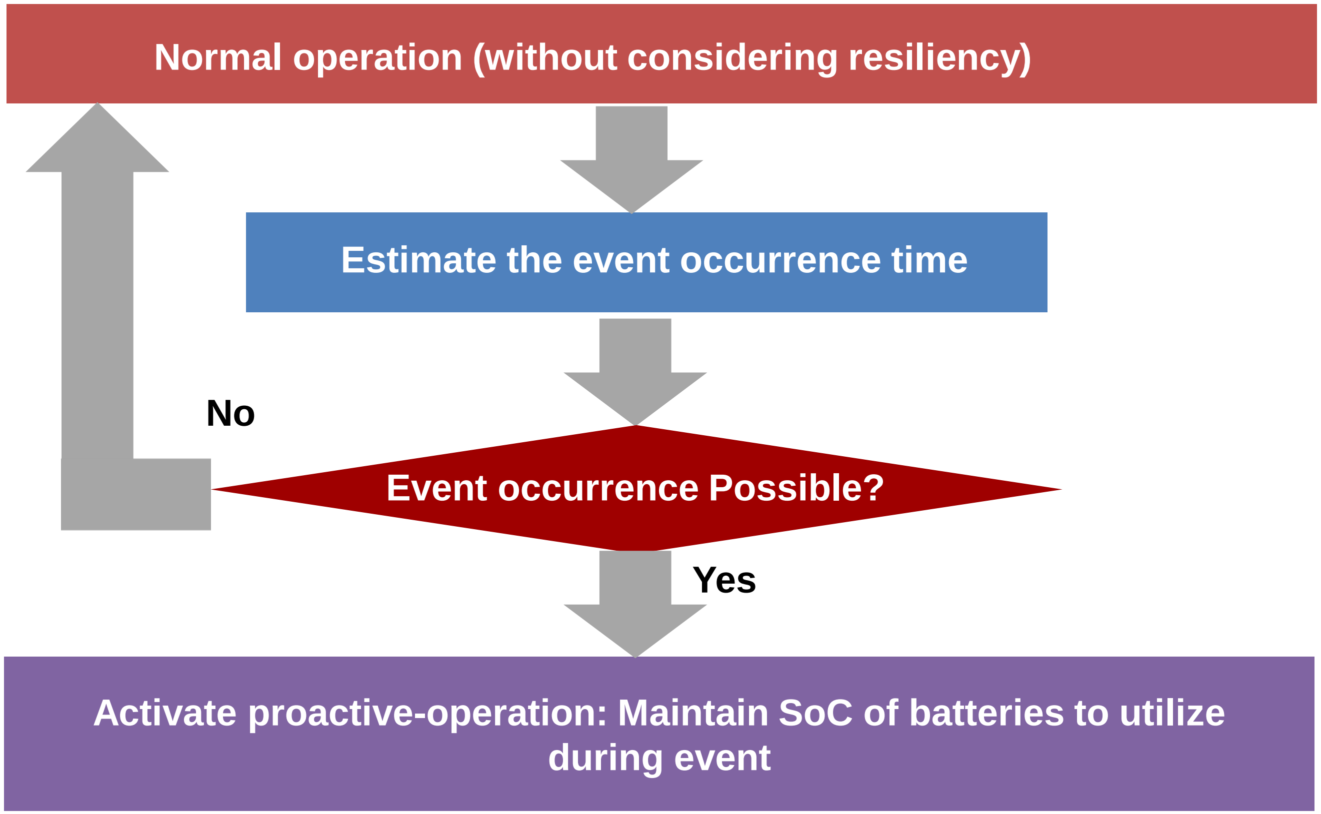
- **Resilient Operation:** The objective is to minimize the load shedding amount and to maximize survivability during events.
- **Before the Event:** Prepare the microgrid to minimize the load shedding during events
- **During the event:** Maximize the survivability of loads, especially critical loads

Challenges in resilient operation

1	2	3
Event Time	**Resources**	**Duration**
Event occurrence time is not known precisely	Limited resources are available during the event	Event duration is not known precisely

Resilient Operation

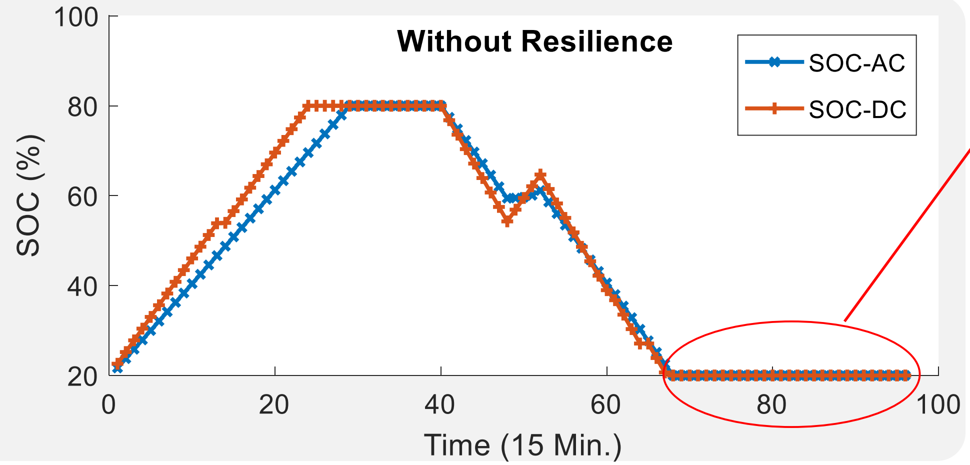
Preparation Phase [Readiness for Potential Events]



Resilient Operation

Proactive Operation Results

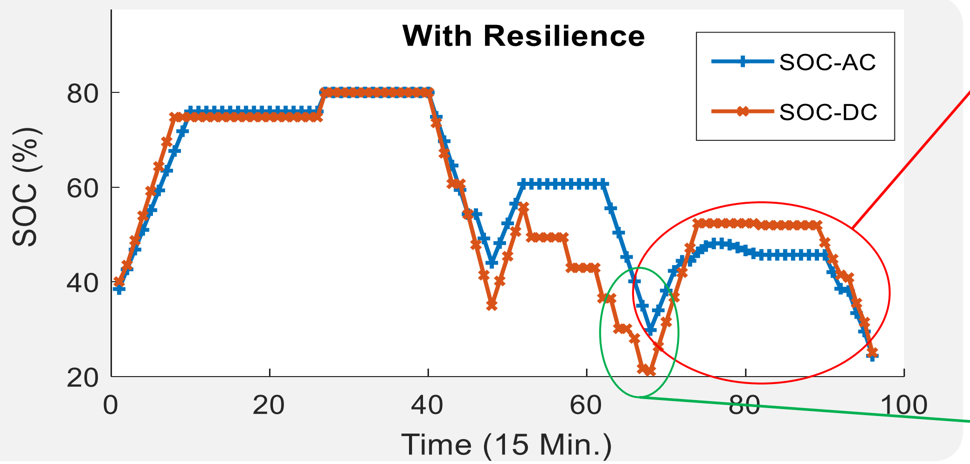
Without Resilience Algorithm



SoC is reduced to Min. level for increasing operation profit

Objective is Cost minimization

With Resilience Algorithm



SoC is maintained to enhance the survivability during events

Objective is Reliability maximization

Due to higher renewables, SoC is reduced to Min. Level

Other intervals maintain SoC

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Resilient Operation

Survivability Enhancement Scheme [Emergency Operation]

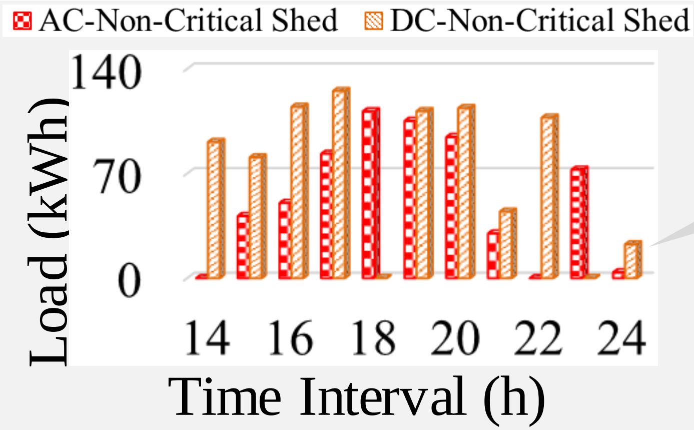
The objective is to maximize the survivability of critical loads during the event time

- **Define Priorities for Load**, available resource may not be sufficient to fulfil all the loads during the event period
- **Maintain SoC:** to survive critical loads, event duration is not accurately known and renewables are uncertain.
- **Shift Load-Shedding Towards End:** The event duration is not know, shifting load shedding towards end can potentially avoid unnecessary load shedding.

Resilient Operation

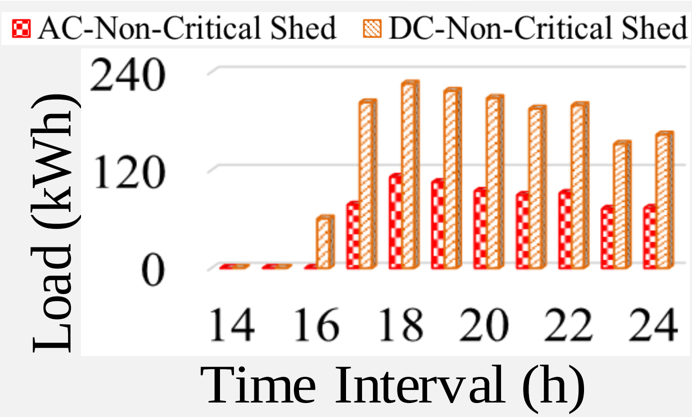
Survivability Enhancement Results

Without Resilient Algorithm



Load shedding is carried-out randomly, decided by the optimization algorithm

With Resilient Algorithm



Load shedding is shifted towards the end of the scheduling horizon.

This can avoid unnecessary load shedding, if event is cleared earlier

Incorporation of BESS Model in EMS

Limitations of BESS Model In EMS

- The resiliency depends on amount of energy available in the batteries but incorrect estimation of SoC can reduce the resilience
- Generally, battery model in EMS is simplified and it results in SoC mismatch

Factors causing SoC mismatch

The operation interval of EMS is in minutes or hours but the SoC of batteries changes more frequently

Linearized charging/discharging efficiencies are utilized in EMS but efficiencies changes non-linearly in batteries

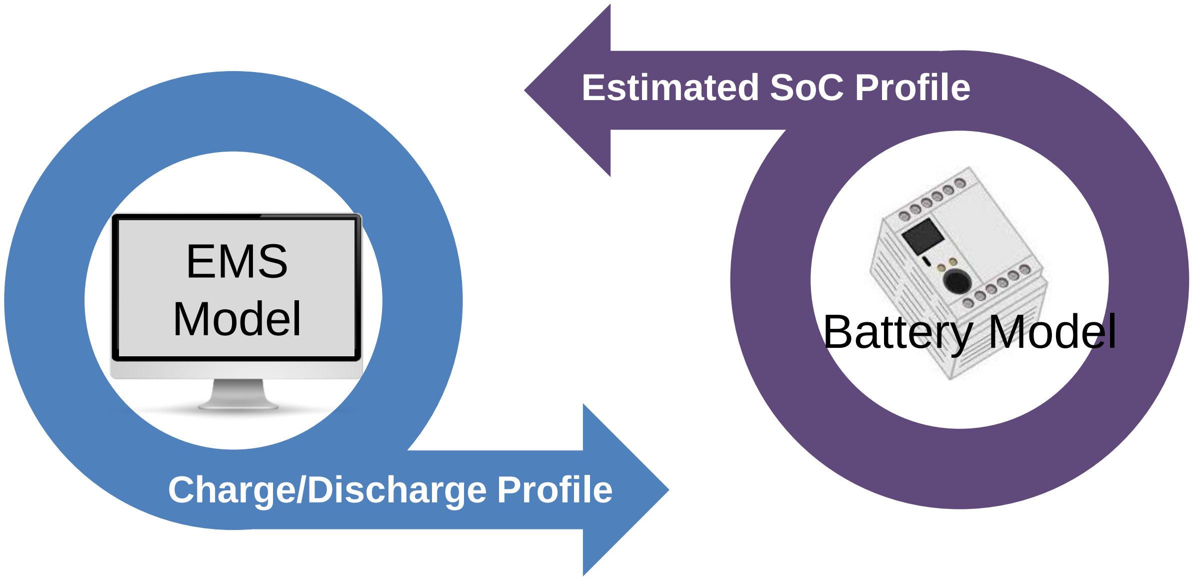
Internal resistance is ignored in EMS but it influences the SoC and varies with the life of BESS

* EMS: Energy Management System; BEMS: Battery Energy Management System

Incorporation of BESS Model in EMS

Incorporation Method

Challenging to operate both models together due to difference in model fidelity and utilization of different quantiles for SoC computation

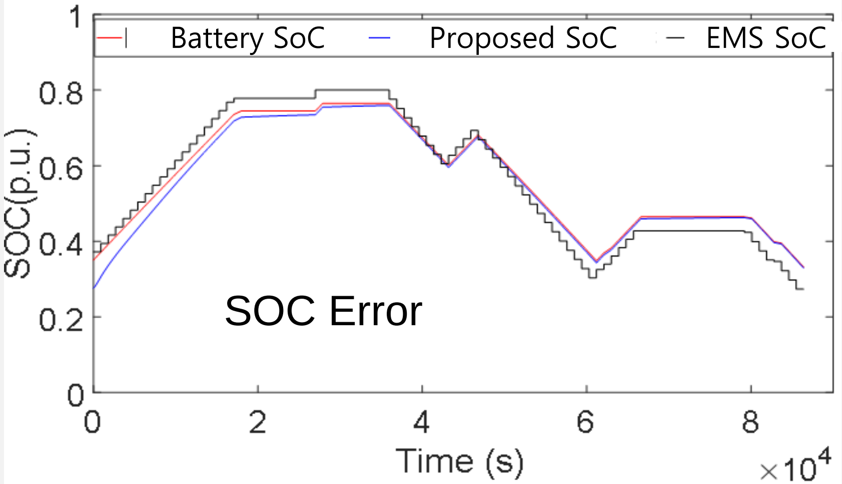


- EMS runs optimization and sends charging/discharging profiles to battery model
- Battery model estimates SoC and send the SoC profile to EMS (every operation intervals)
- EMS checks the error and optimizes if the error is big enough

Incorporation of BESS Model in EMS

SoC Discrepancies in EMS Model

SoC Discrepancy in EMS and BEMS



The proposed SoC converges to the SoC of battery (real SoC), thus resiliency will not be compromised.

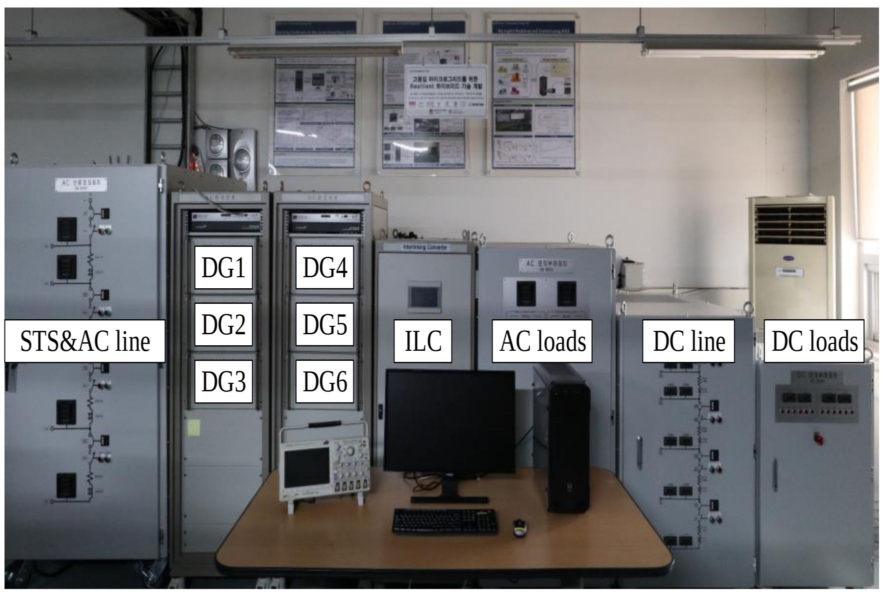
There is discrepancy between the battery SoC and the SoC of EMS

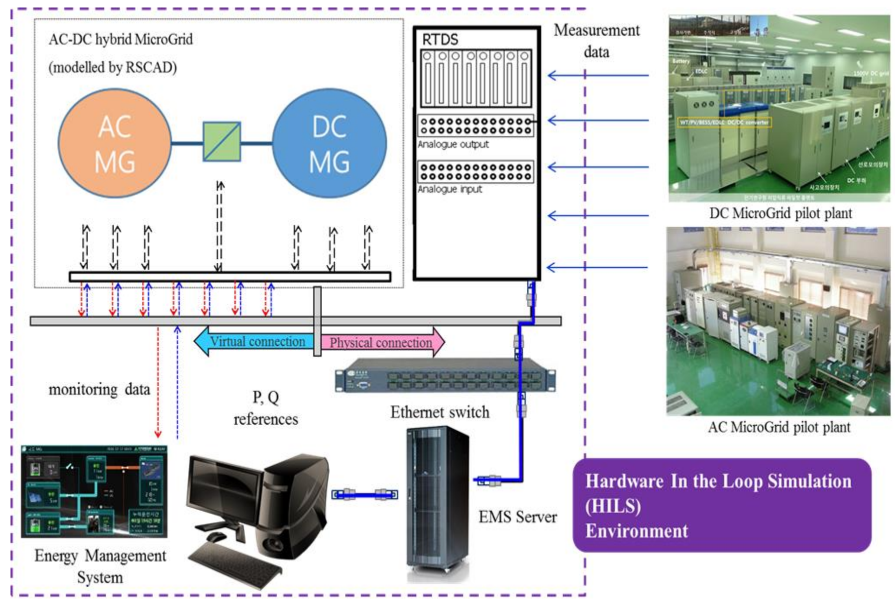
RHYTHM Project Overview

Core Control Tasks & Testbed

Core Tasks

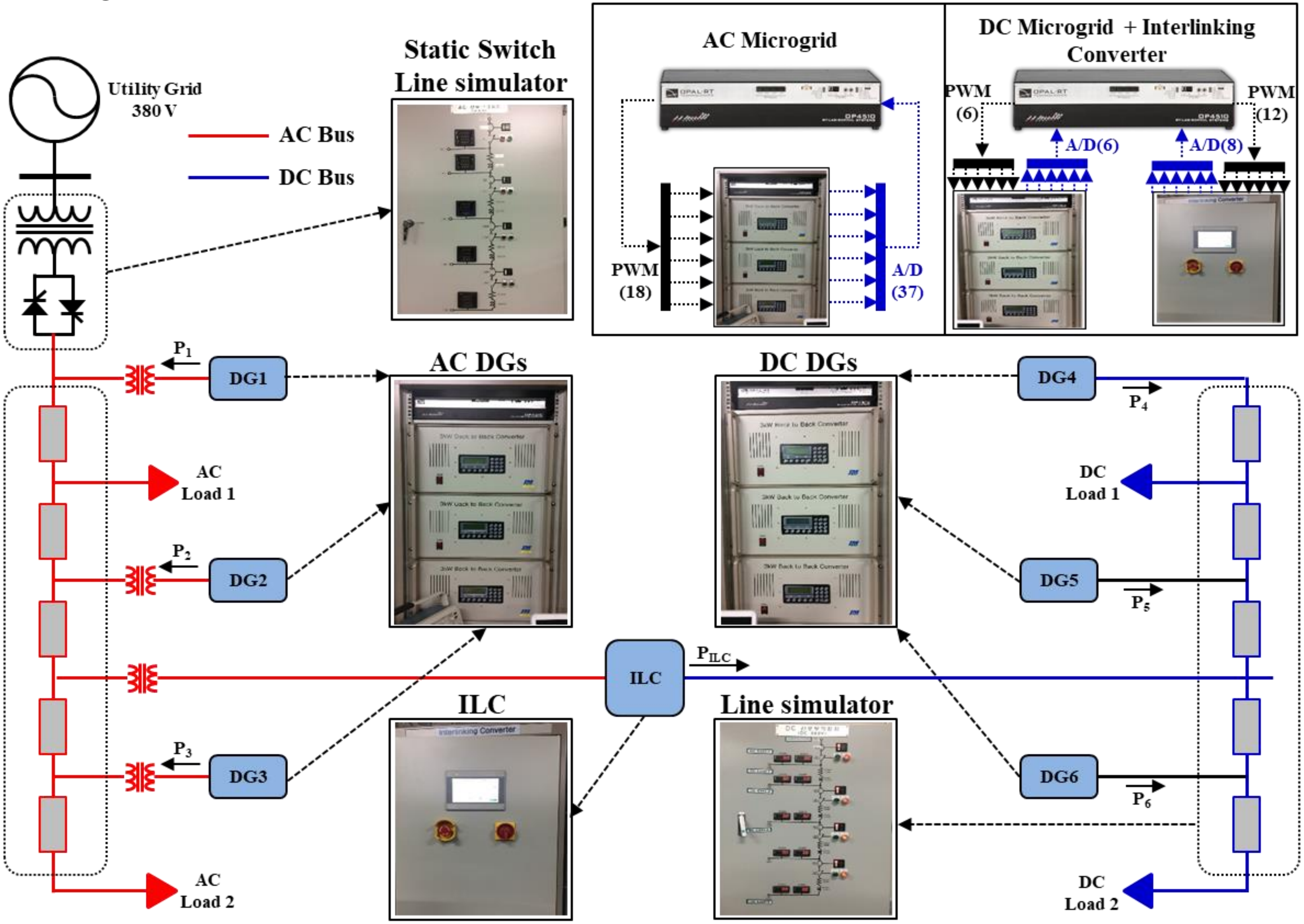
- To develop AC control algorithm to improve resilience (by Chungbuk Nat'l Univ.)
- To develop DC control algorithm to improve resilience (by Hanyang Univ.)
- To develop ILC control algorithm to improve resilience (by Incheon Nat'l Univ.)
- To develop HILS-based Testbed (by Incheon Nat'l Univ.)
- To test performance (Korea team and Imperial College London)





Control Strategy for AC-DC Hybrid MG

System Configuration of HILS-based Testbed



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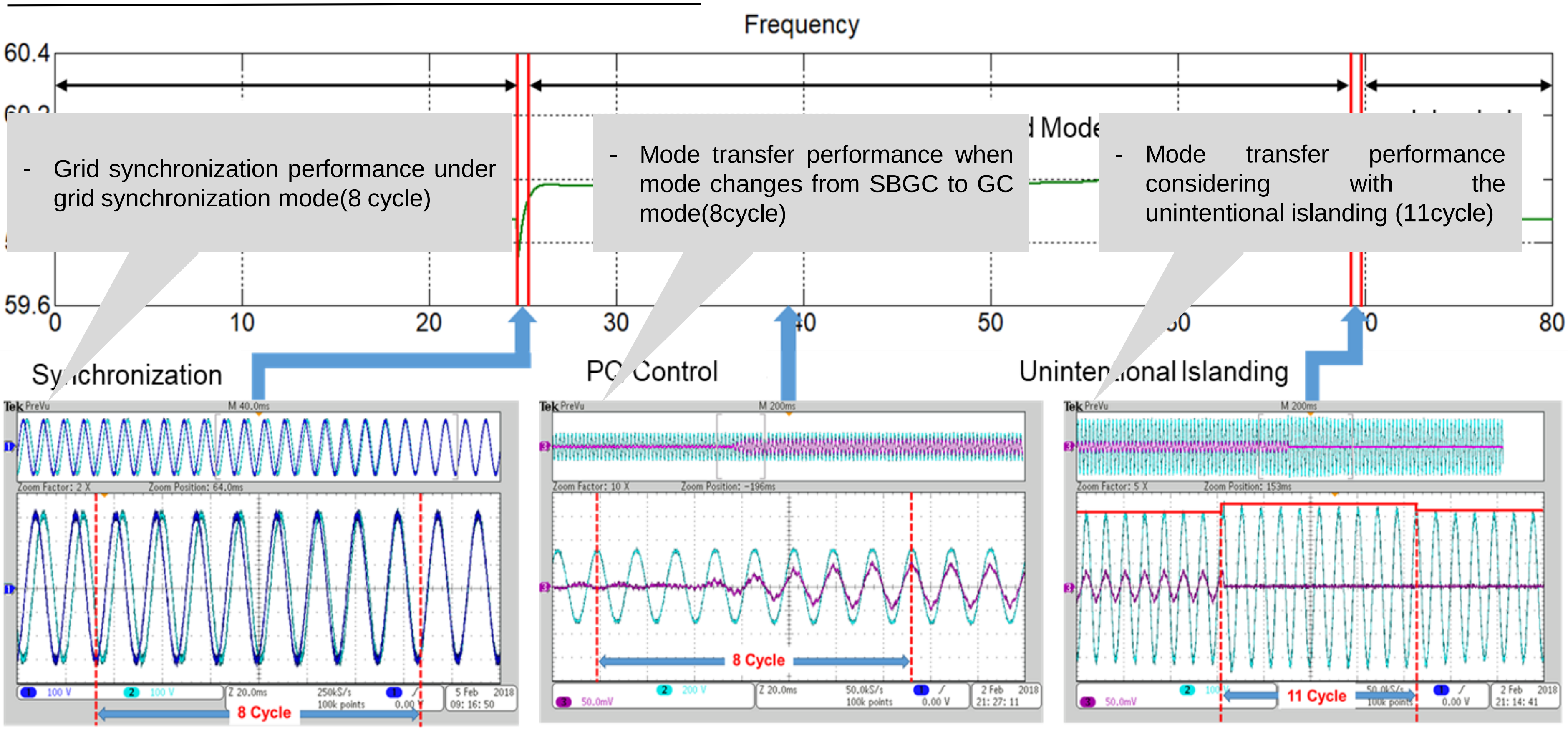
Control Strategy for AC-DC Hybrid MG

An Example of AC Microgrid Control

Test Results of Seamless Grid Synchronization



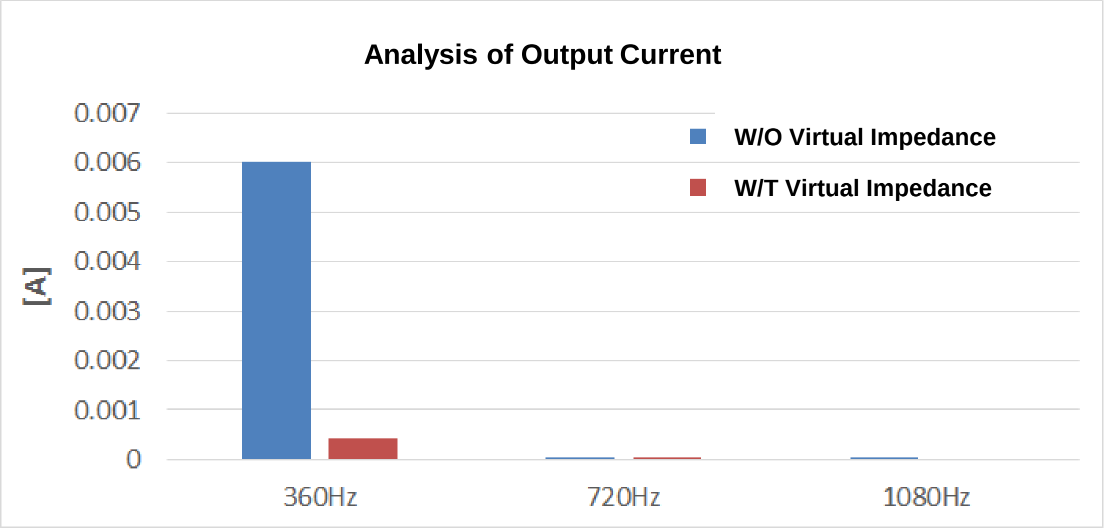
- SBGC: Standby mode for grid connection
- GC: Grid connection

Control Strategy for AC-DC Hybrid MG

An Example of AC Microgrid Control

Test Results of Improving Stability by Virtual Impedance

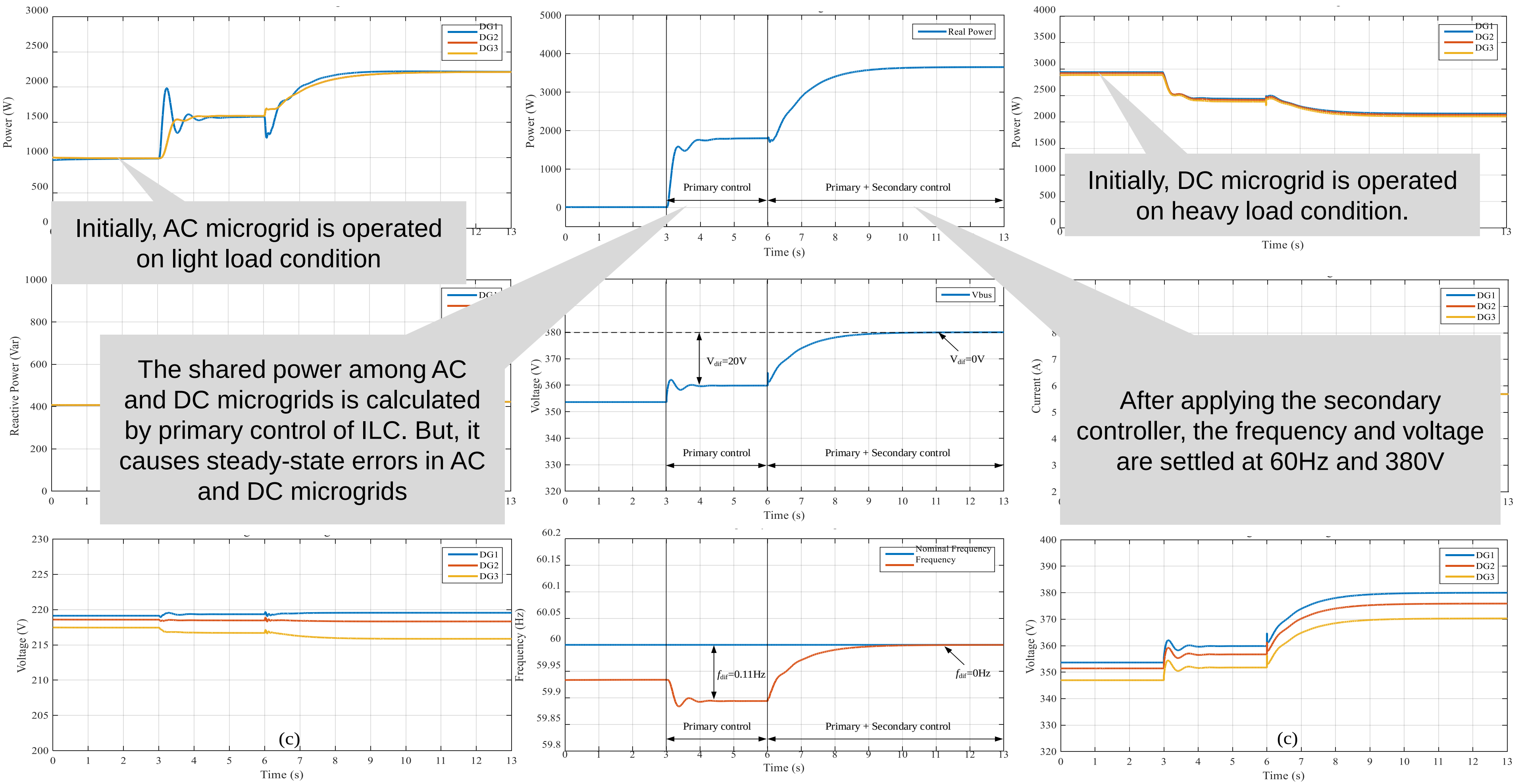
- Compare Before applying VI and After applying VI



✓ Decrease of total harmonic distortion(THD) → Improving converter stability

Control Strategy for AC-DC Hybrid MG

ILC Test – Coordinated control of AC and DC microgrids using ILC



<AC Microgrid> <Interlinking Converter> <DC Microgrid>

* ILC: Interlinking Converter

Collaborative Activities

RHYTHM Workshops in Korea and UK

May-2017
Incheon National University, Korea

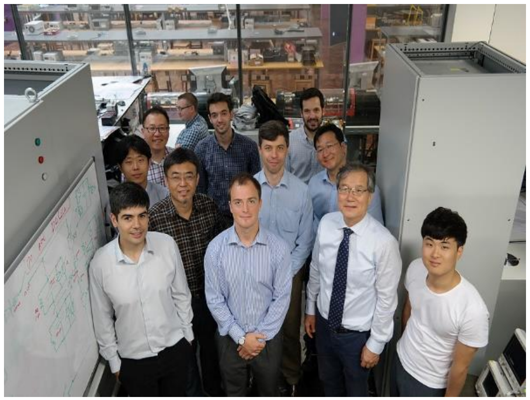
July 2016
Imperial College London, UK

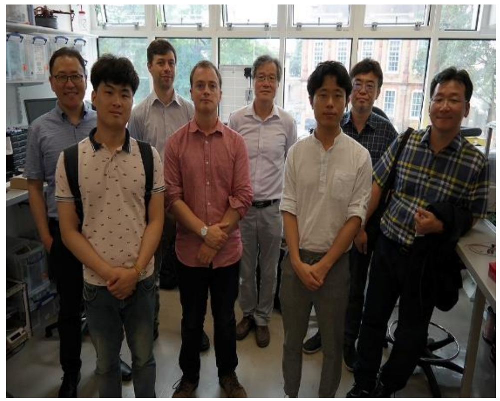
May 2018
KERI, Changwon, Korea

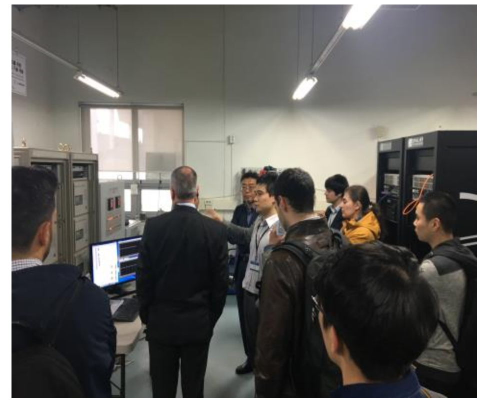
July 2017
Oxford University, UK

Collaborative Activities

Visiting & Exchanging Researchers







Conclusions

Project Overview

An overview of the project including budget, research team, and goals are presented.

Resilient Control

Hybrid AC-DC MG control schemes developed are summarized.

Resilient Operation

Resilient EMS algorithm and impact of high fidelity battery model are analyzed.

Research Collaboration and Outcomes

Research exchanges and outcomes of the project are summarized.

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Thank you for your attention

Questions…?