ECOLE NATIONALE POLYTECHNIQUE D'ORAN-MAURICE AUDIN
Laboratoire SCAMRE
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Research theme : electrical smart grids & renewable energies integration

Real time digital simulation of battery energy storage system contribution to reduce active power fluctuation in a micro-grid

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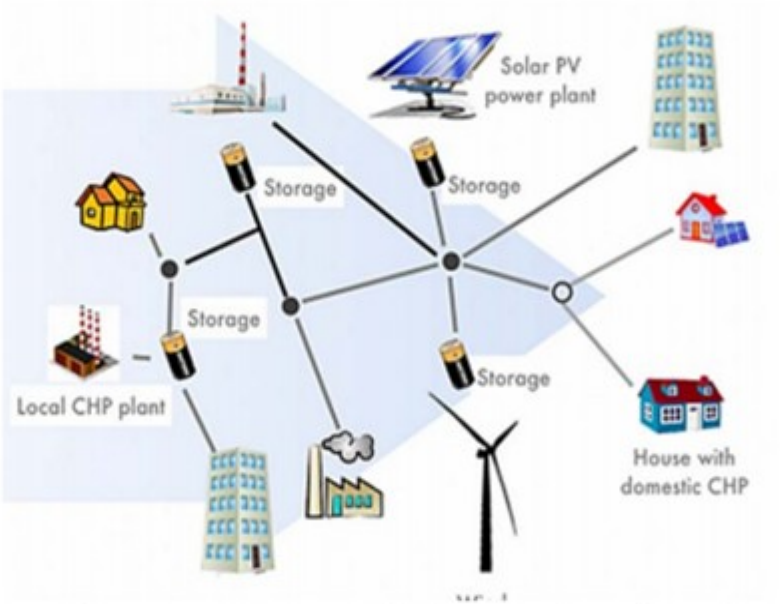
Work plan

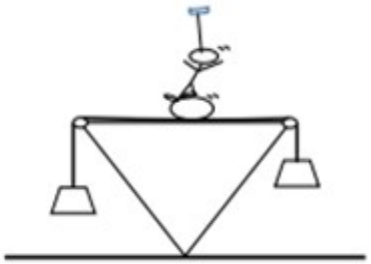
- Context & Motivation
- Micro-grid architecture
- BESS operation within energy management system (EMS)
- Real-time simulation
- RT-LAB micro-grid model description
- Real-time simulation results
- Conclusion & futur perspective

Context & Motivation (1/2)

Evolution of Distribution Systems : from passive to SMART Active Distribution Systems and Micro-Grids with distributed generation

- ➔ Becoming as complex as transmission systems
- ➔ Security and performance relies on more complex controls, protection and communication systems
- ➔ Design and Testing an integrated system interconnected with the main grid becomes a challenges





- ❖ Renewable energy systems (solar, wind, etc) are less predictable
- ❖ Use of power electronics, fast protection system
- ❖ Use of wide area control and protection systems (SPS)
- ❖ Sophisticated communication systems and protocols

Context & Motivation (2/2)

Impacts of penetration of the renewable energies into the electrical power networks :

- Generate perturbations and instability in the power grid if they are not well managed ;
- Intermittent nature of renewable energies with unpredictable power fluctuations ;
- Instantaneous power unbalances.

Proposed solution:

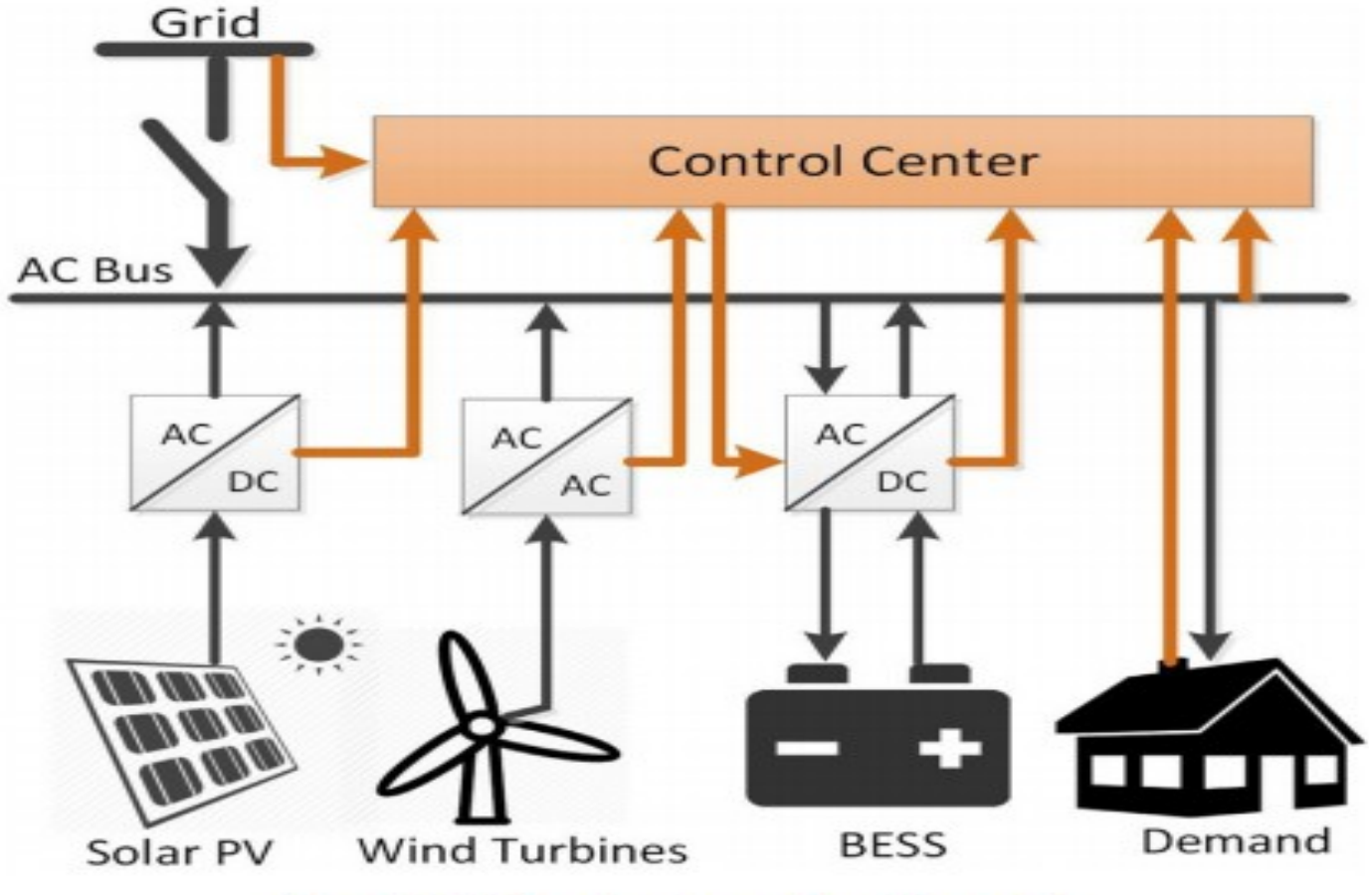
- Battery Energy Storage System (BESS) is the most used recently on micro-grids in order to reduce the undesirable effects such power fluctuations, maintain power balance and manage the integration of intermittent of energy resources.

Objectives of the study :

To verify the behavior of a BESS and how it manages its state-of-charge (SOC),

How quickly an BESS can deliver power in response to any phenomena.

Micro-grid architecture



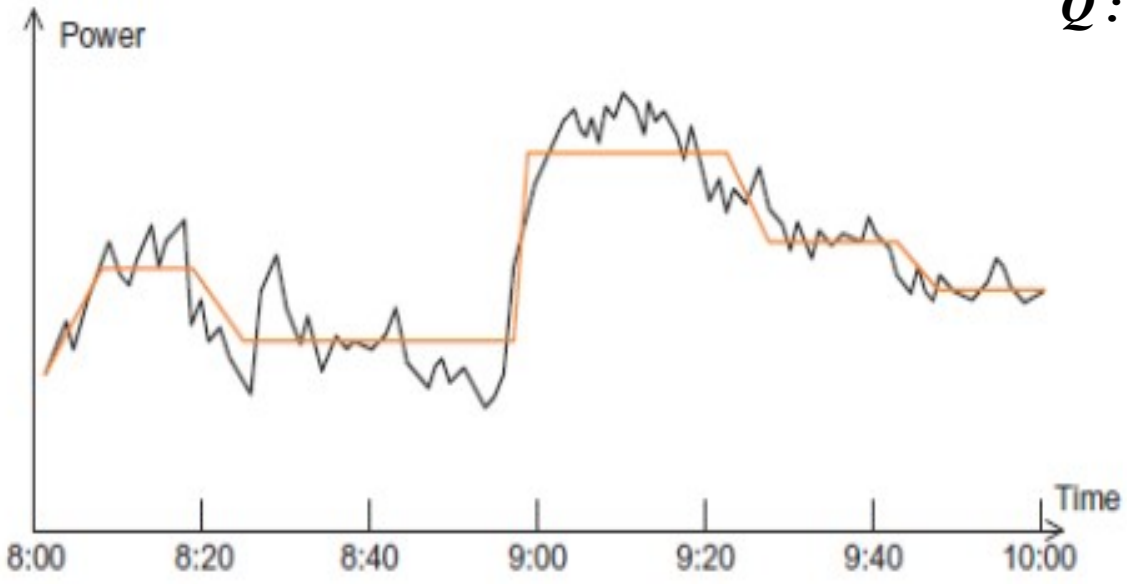
The structure of the micro-grid

BESS operation and energy management system

The two main parameters indicating power system stability are : frequency and voltage

F = f(P)
V = f(Q)

F : frequency (Hz)
P : Active power (Watt)
V : Voltage (Volt)
Q : Reactive Power (VAR)



Principle of load consumption: without BESS (black) and with BESS (red)

Real time simulation

Early faults detection, more test in the lab, less tests on-site.

Real-Time simulation benefits:

1. Gaining time:

- ✓ Allowing engineers to gain time in the testing process.
- ✓ Find problems at an earlier stage the design process

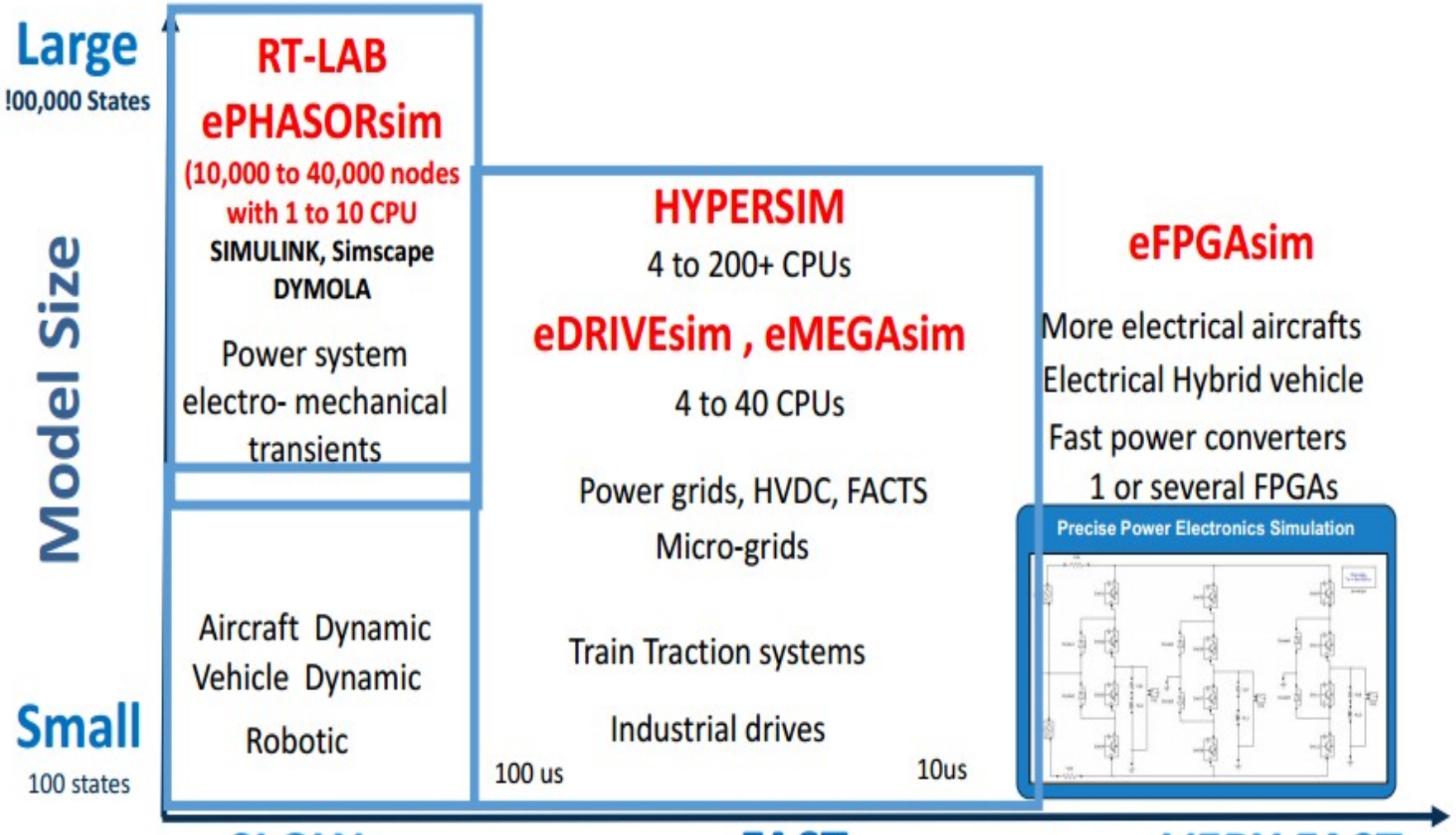
2. Lowering cost:

- ✓ Reduce enormous cost on testing a new device under real conditions.
- ✓ The real-time system could test many possible configurations without physical modification.

3. Increasing test functionalities:

- ✓ Test all possible scenarios that could happen in real life in a secure and simulated environment.
- ✓ High flexibility by being able to modify all parameters and signals of the test system at a glance.

OPAL-RT HIL Real-Time Simulation Solutions

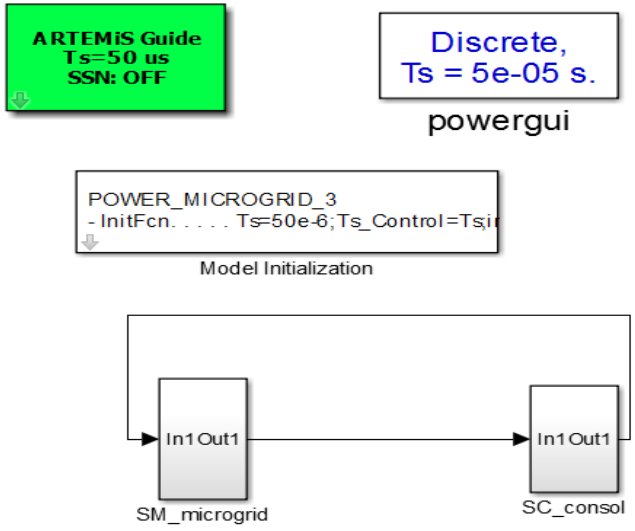


OPAL-RT TECHNOLOGIES

HARDWARE AND SOFTWARE ARCHITECTURE

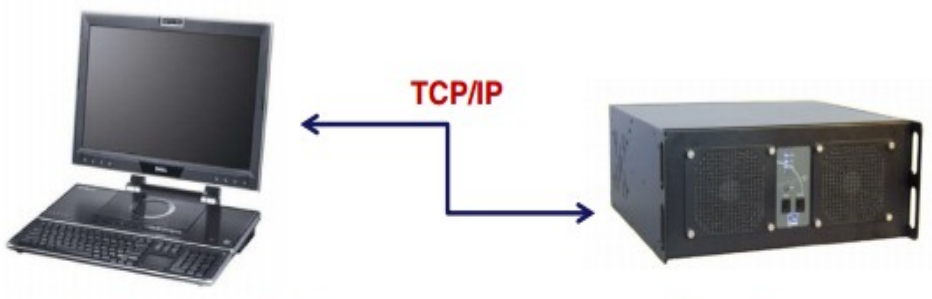
RT-LAB platform :

The real-time simulator used in our work is RT-LAB digital simulator developed by OPAL-RT technologies (Montreal, Canada).



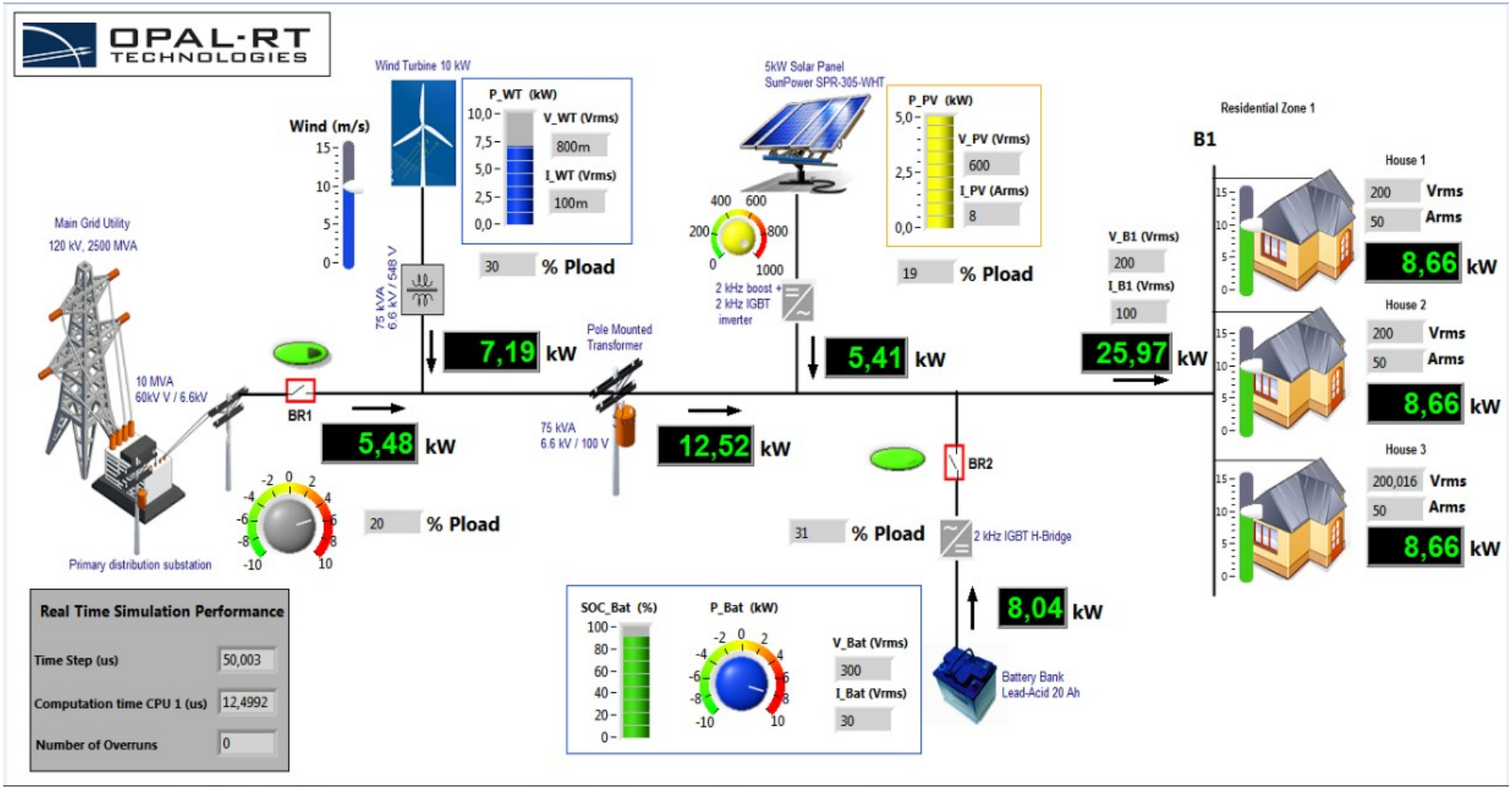
Software architecture ➔

Hardware architecture ➔

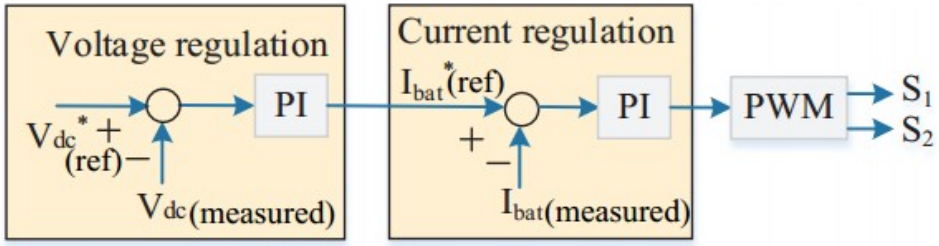


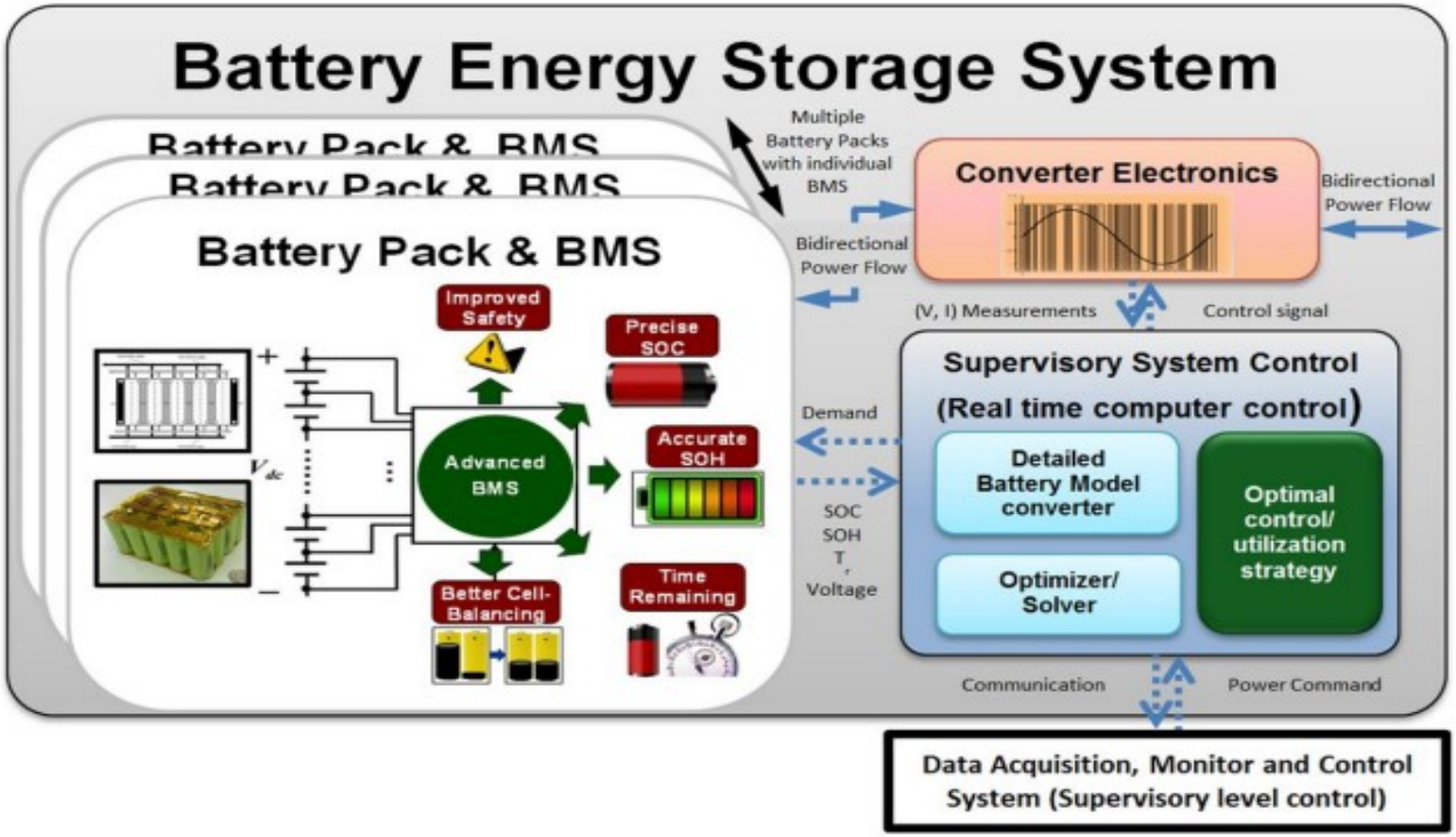
- Edition of Simulink model
- Model compilation with RT-LAB
- User interface
- I/O and real-time model execution
- QNX or Linux OS
- FTP and Telnet communication Possible with the Host

Micro-grid RT-LAB model description



Supervisory System Control





Real-time simulation results

- *In order to compare the effectiveness of energy storage system during critical situations, a comparison between three types of batteries which are connected to the micro-grid is conducted through the following cases:*

Case 1: Only Lead-Acid batteries are connected to the micro-grid

Case 2: Only Lithium-Ion batteries are connected to the micro-grid

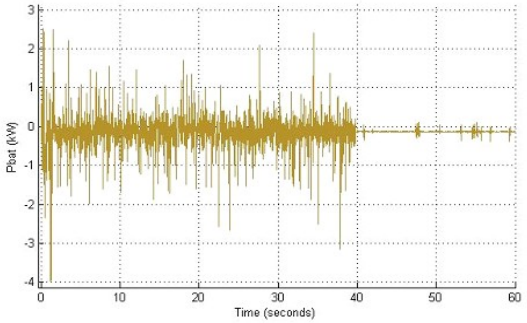
Case 3: Only Nickel-Cadmium batteries are connected to the micro-grid

Battery Parameters

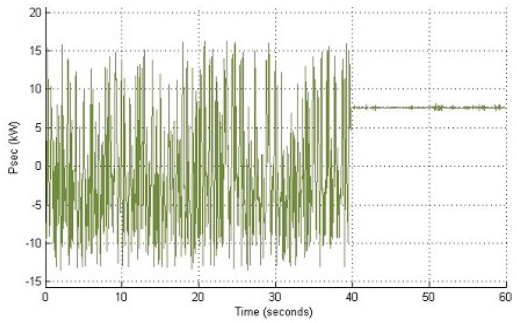
Battery parameters	Battery types		
	Lead-Acid	Lithium-Ion	Nickel-Cadmium
Nominal voltage (Volt)	200*	200*	200*
Rated capacity (Ah)	1000	1000	1000
Initial State-Of-Charge (%)	90	90	90
Maximum capacity (Ah)	1041.6667	1000	1136.3636
Fully charged voltage (Volt)	307.9636	329.2253	323.6214
Nominal Discharge Current (A)	200	434.7826	200
Internal Resistance (Ohms)	0.0028284	0.0028284	0.0028284
Exponential Zone [Voltage (volt) Capacity (Ah)]	[287.9 3.3]	[305.5 49.1]	[301.8 279.5]
Battery Response Time (seconds)	5	5	5

Simulation Results

Lead-Acid batteries response
& Supplied active power

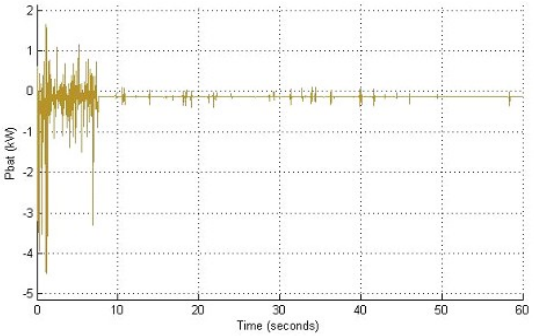


(a)

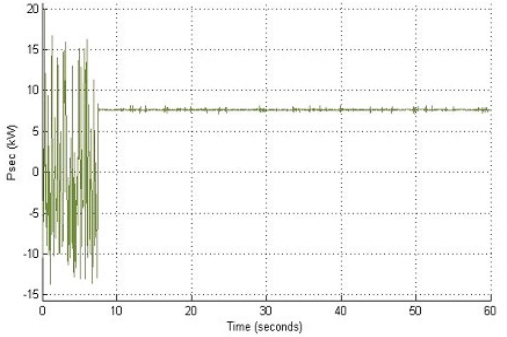


(b)

Lithium–ion batteries response
& Supplied active power

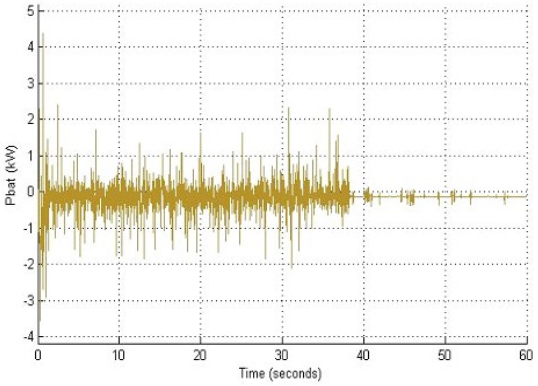


(c)

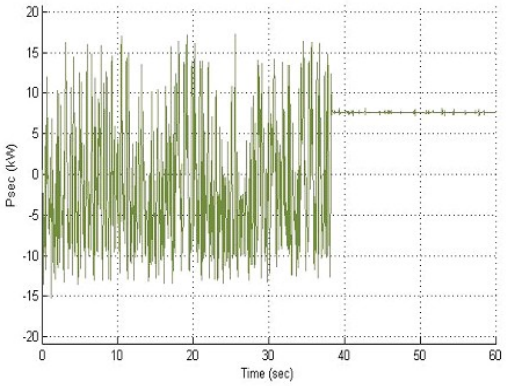


(d)

Nickel-Cadmium batteries response
& Supplied active power



(e)



(f)

Real-time simulation results

- The fast dynamic reponse of a BESS can support network stability during power fluctuations or any disturbance/fault occurrence.

- If a BESS deliver power as quickly as possible, which means that it can deliver more quantity of energy in a short time.

- The difference in response time for the three types of batteries is due to their different material charateristics, and in general the battery performance is determined by its impedance parameters.

Conclusion

- *Based on the real time digital simulation results, it's confirmed that the battery energy storage is an efficient solution for reduction of active power fluctuation in the micro-grid due to its fast response.*

- *The Lithium-Ion batteries are the most suitable solution among other types batteries energy storage for micro-grid operation and stability due to its technical benefits for power by improving safety, reliability and flexibility of the electrical grid, and network management.*

- *As a future perspective, in order to confirm about the efficiency of energy storage system on micro-grid operation, the proposed work will be implemented as experimentation and do a comparison between experimental results and the real time simulation ones.*

Thank you for your attention