« EMR Photovoltaic Nano-grid Modeling and Diesel Generator Usage Optimization »

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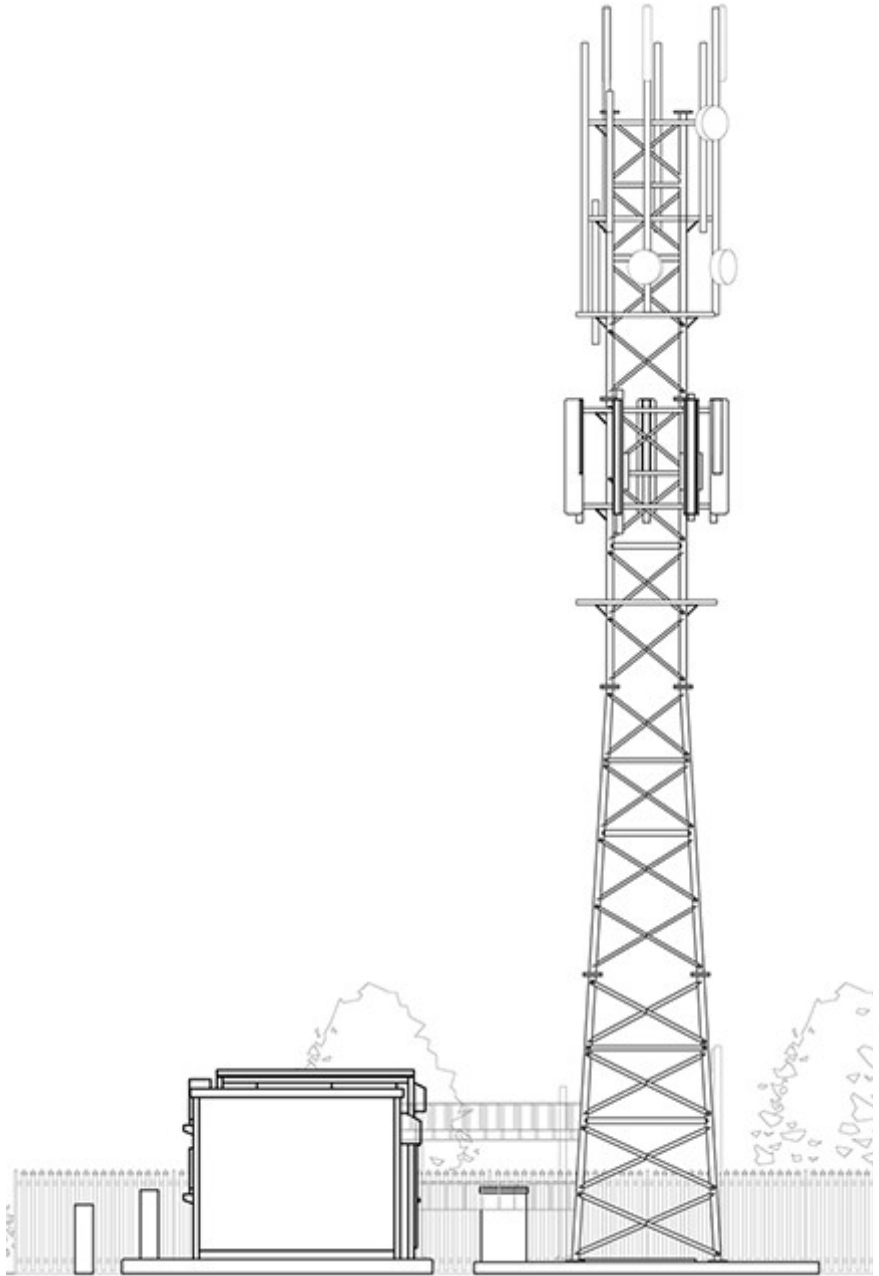
- Outline -

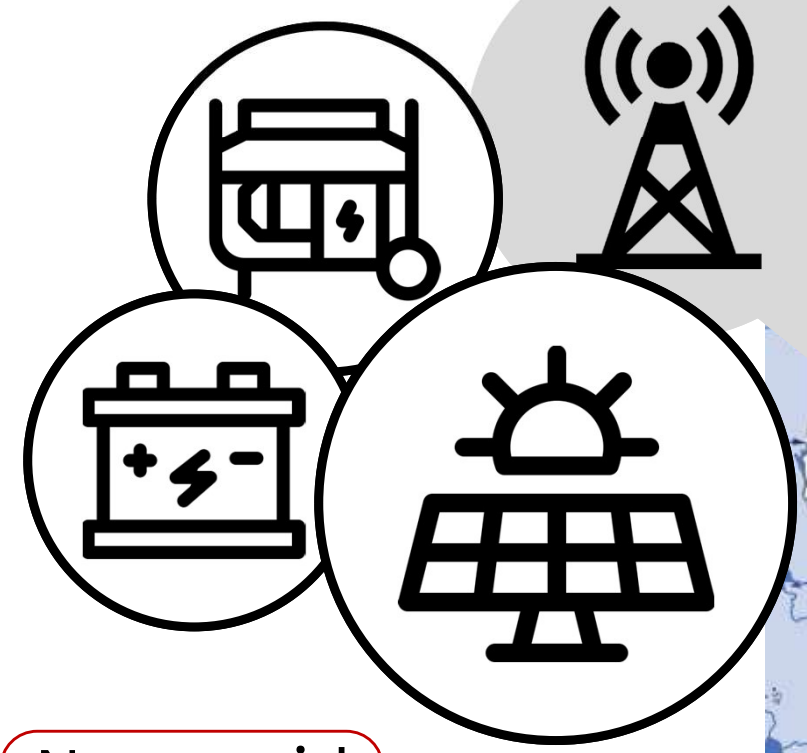
1. Context
2. System modeling
3. Model Validation
4. Control Optimization
5. Conclusions

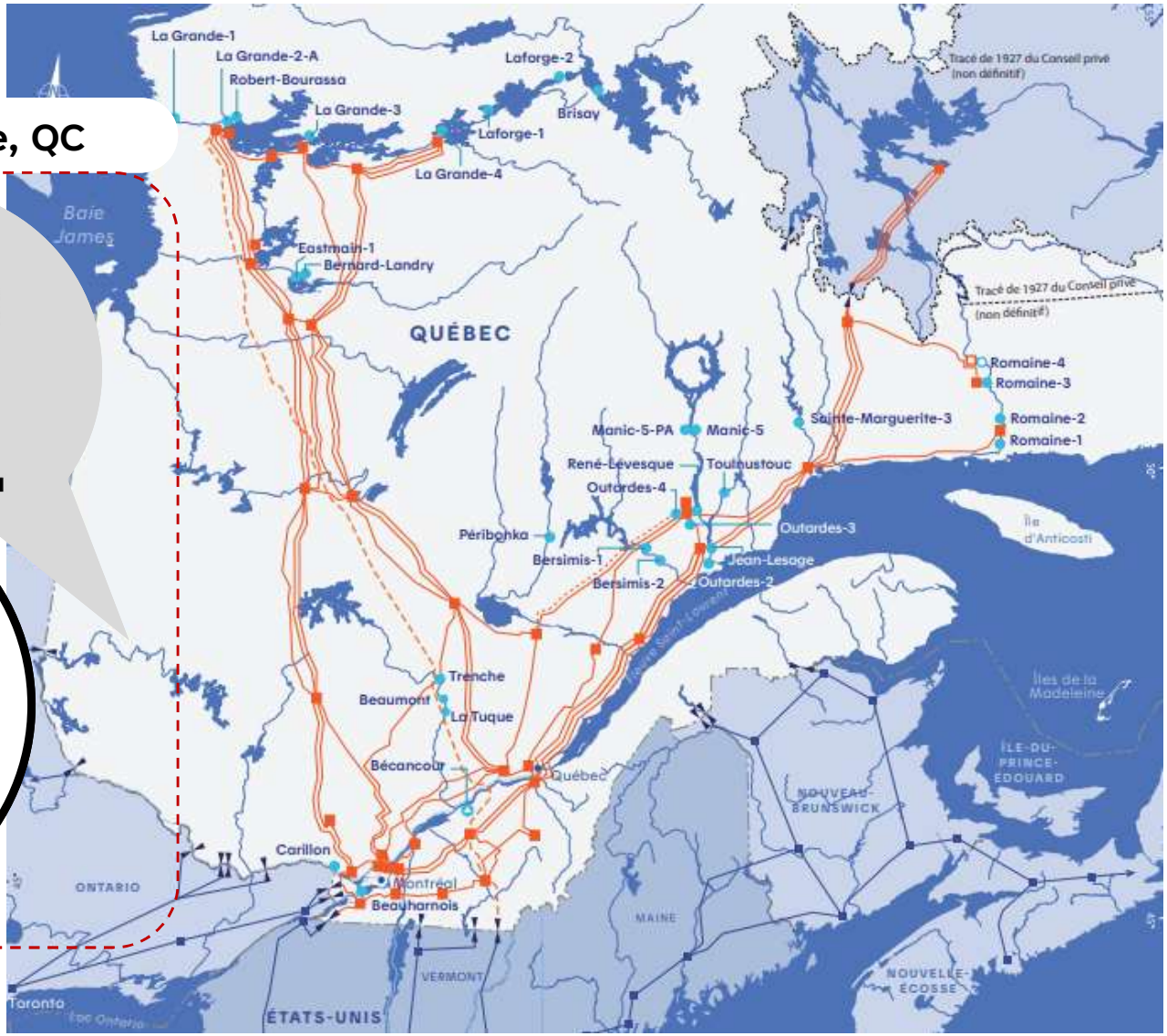


« Context »

- Where is the application? -

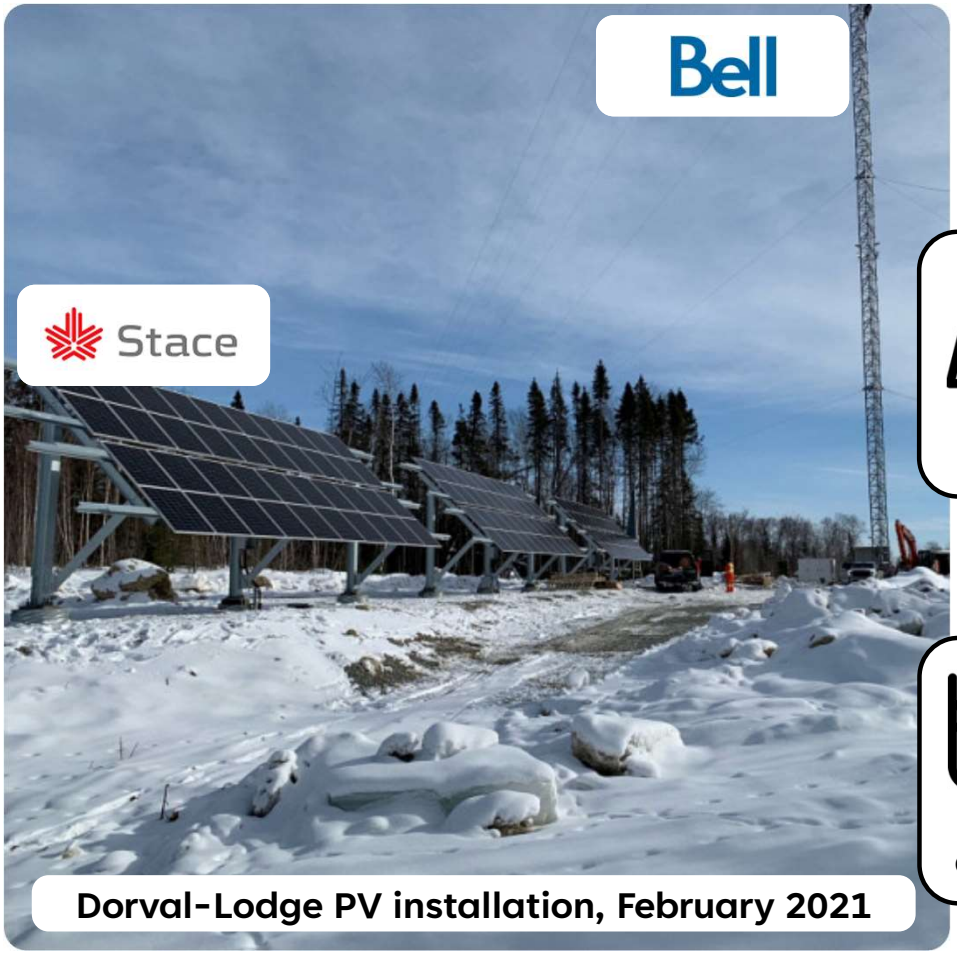
Dorval-Lodge, QC



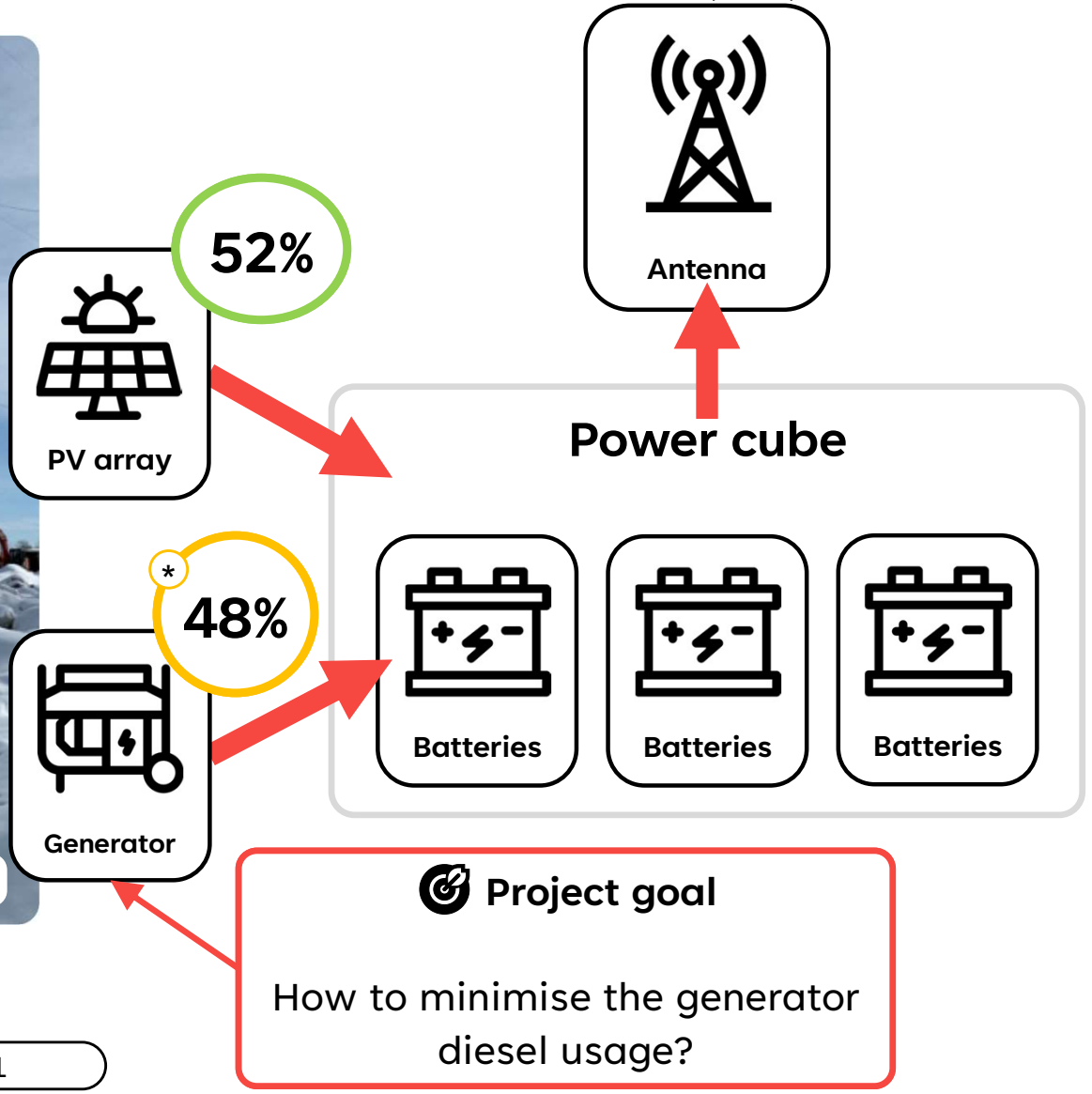


Hydro-Québec high voltage grid [1]

- What is the system? -

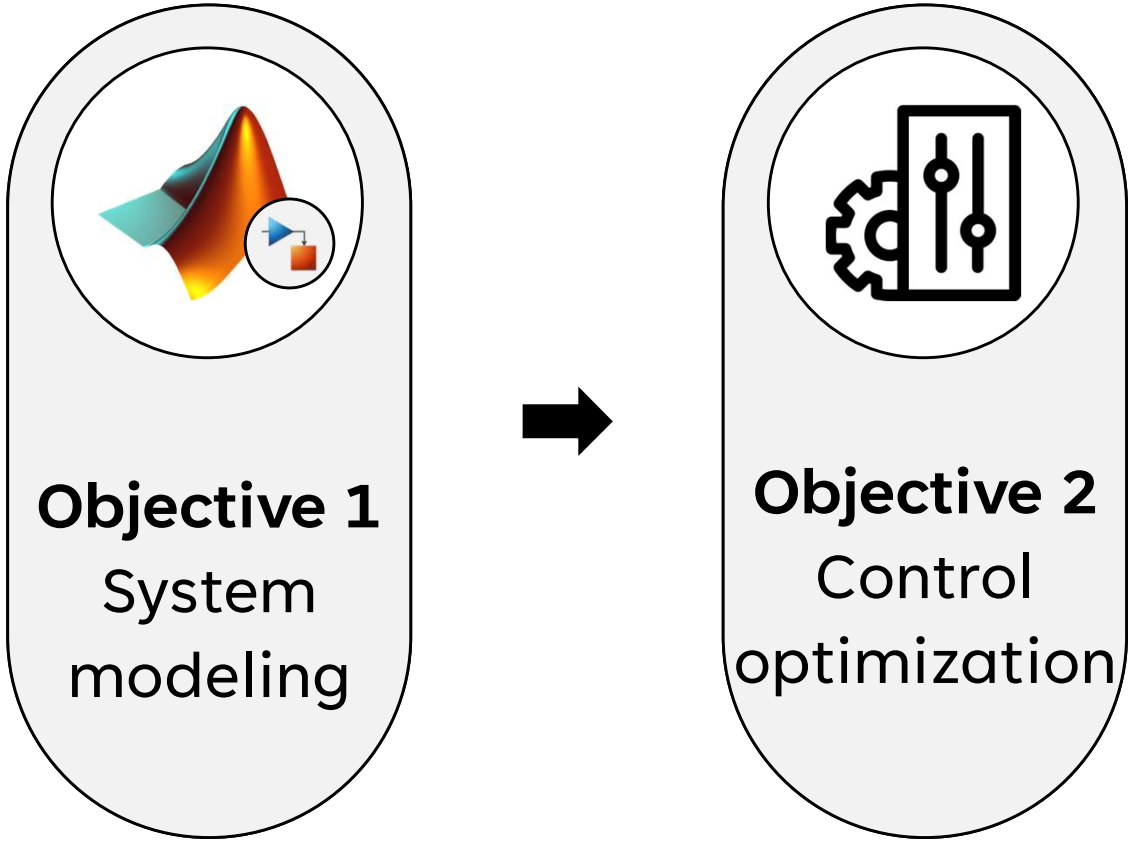


Dorval-Lodge PV installation, February 2021

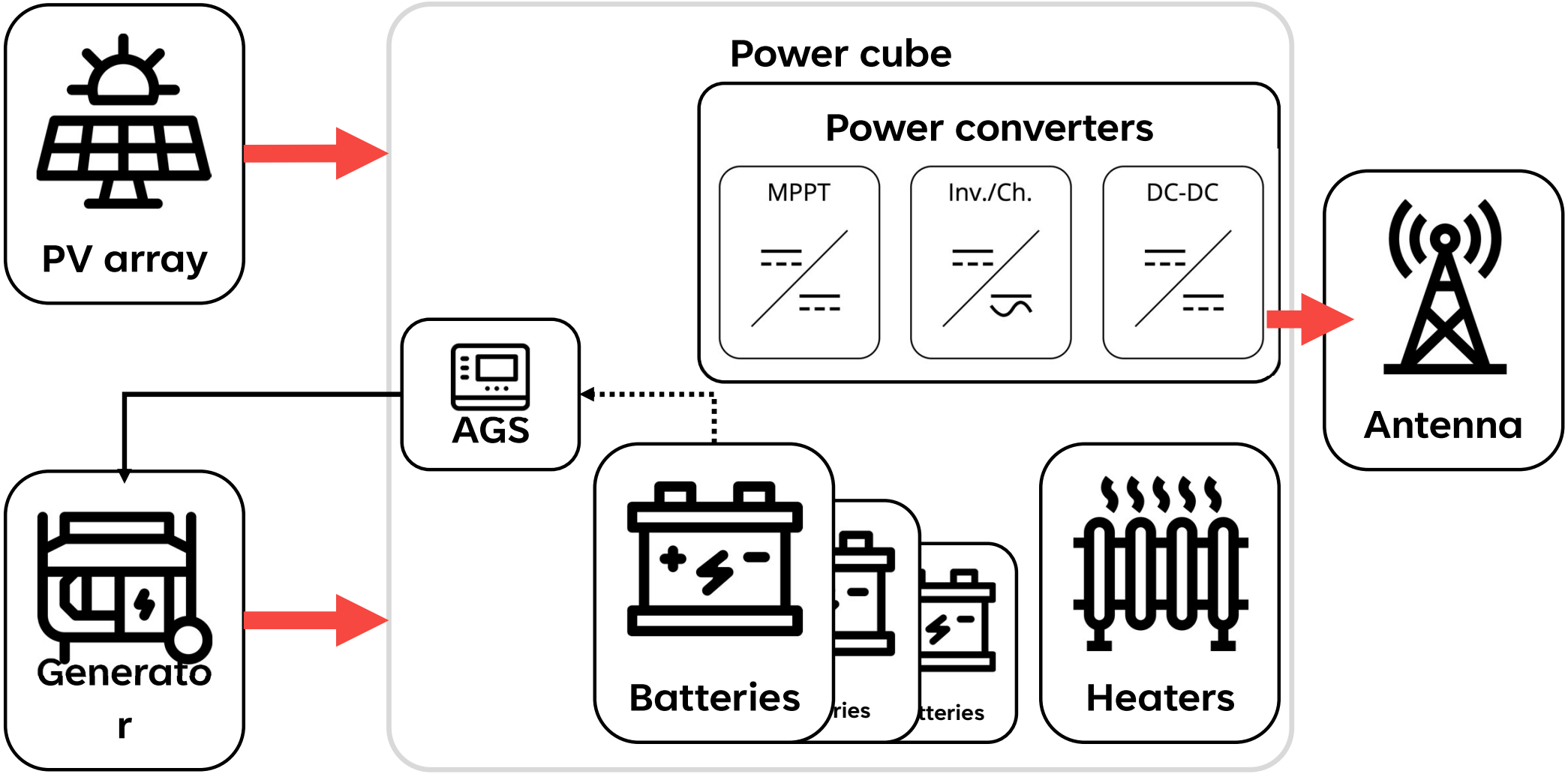


* Energy contribution of the installation since February 2021

- How to achieve this goal? -



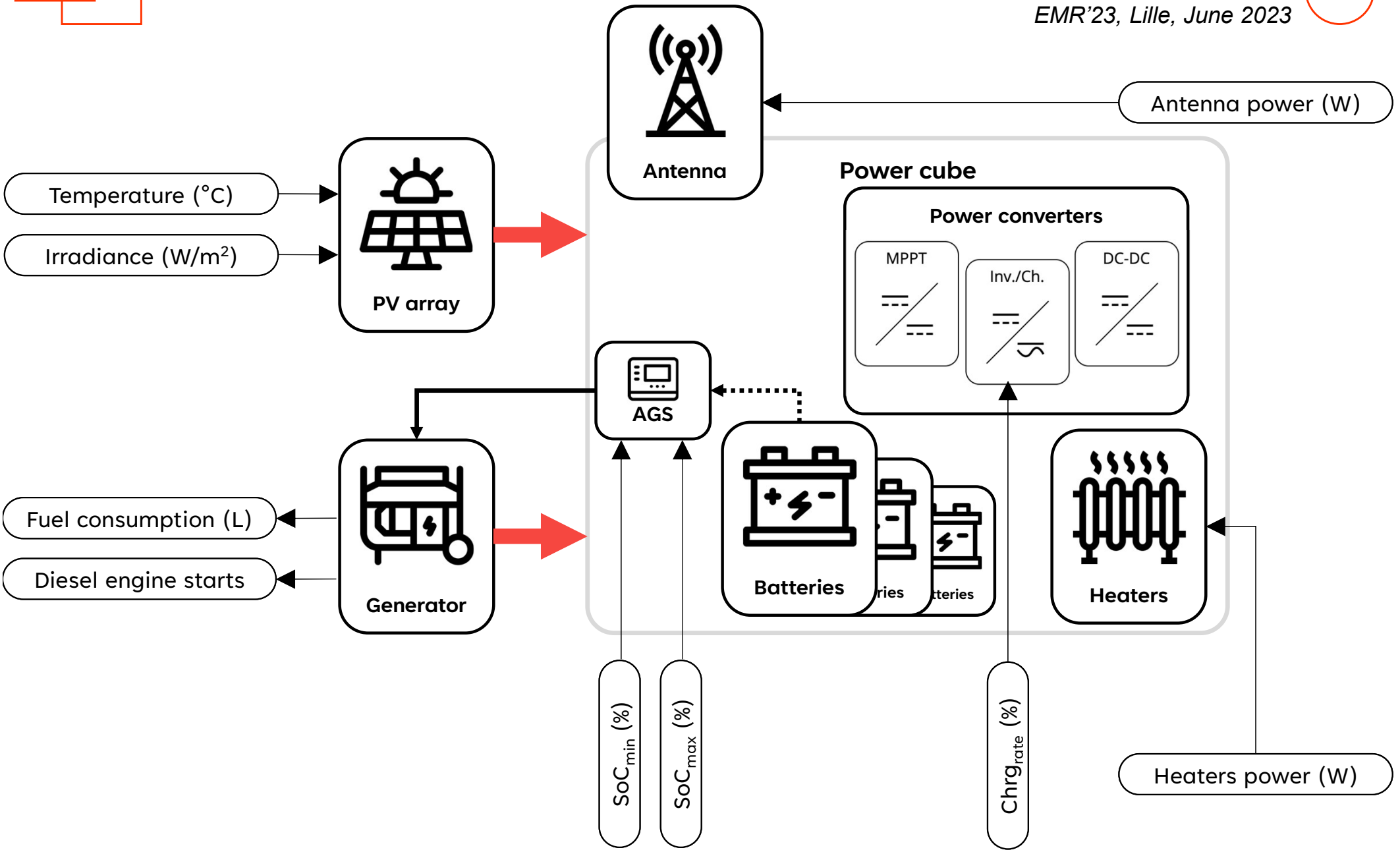
- System Architecture -



AGS: **A**utomatic **G**enerator **S**tarter

« System Modeling »

- System Architecture -

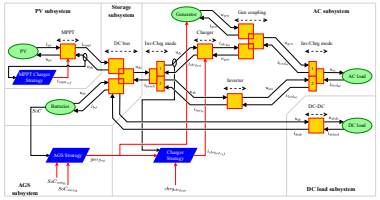


- Model inputs and outputs -

Timeseries inputs

- Temperature (°C)
- Irradiance (W/m²)
- Heaters power (W)
- Antenna power (W)

Model

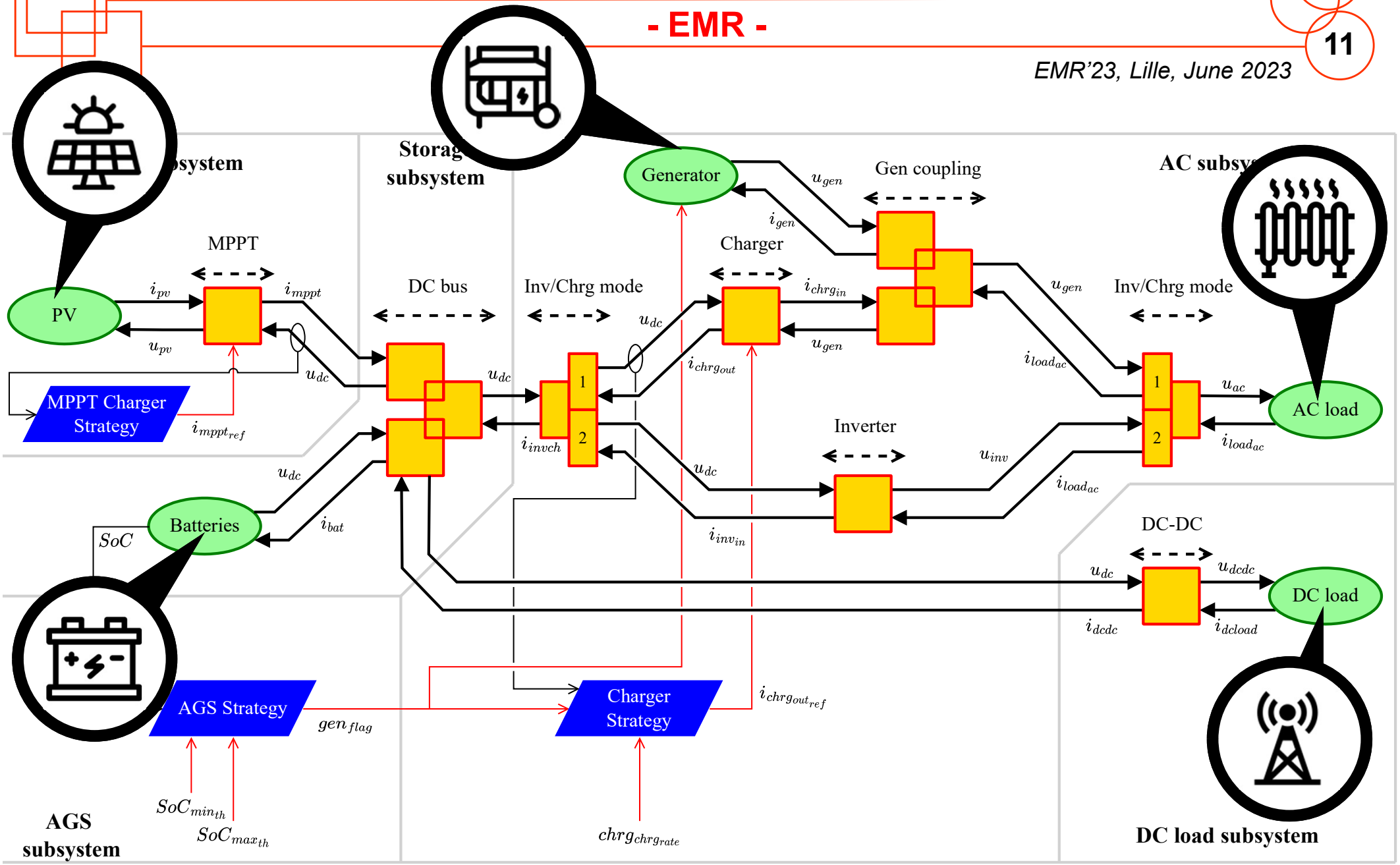


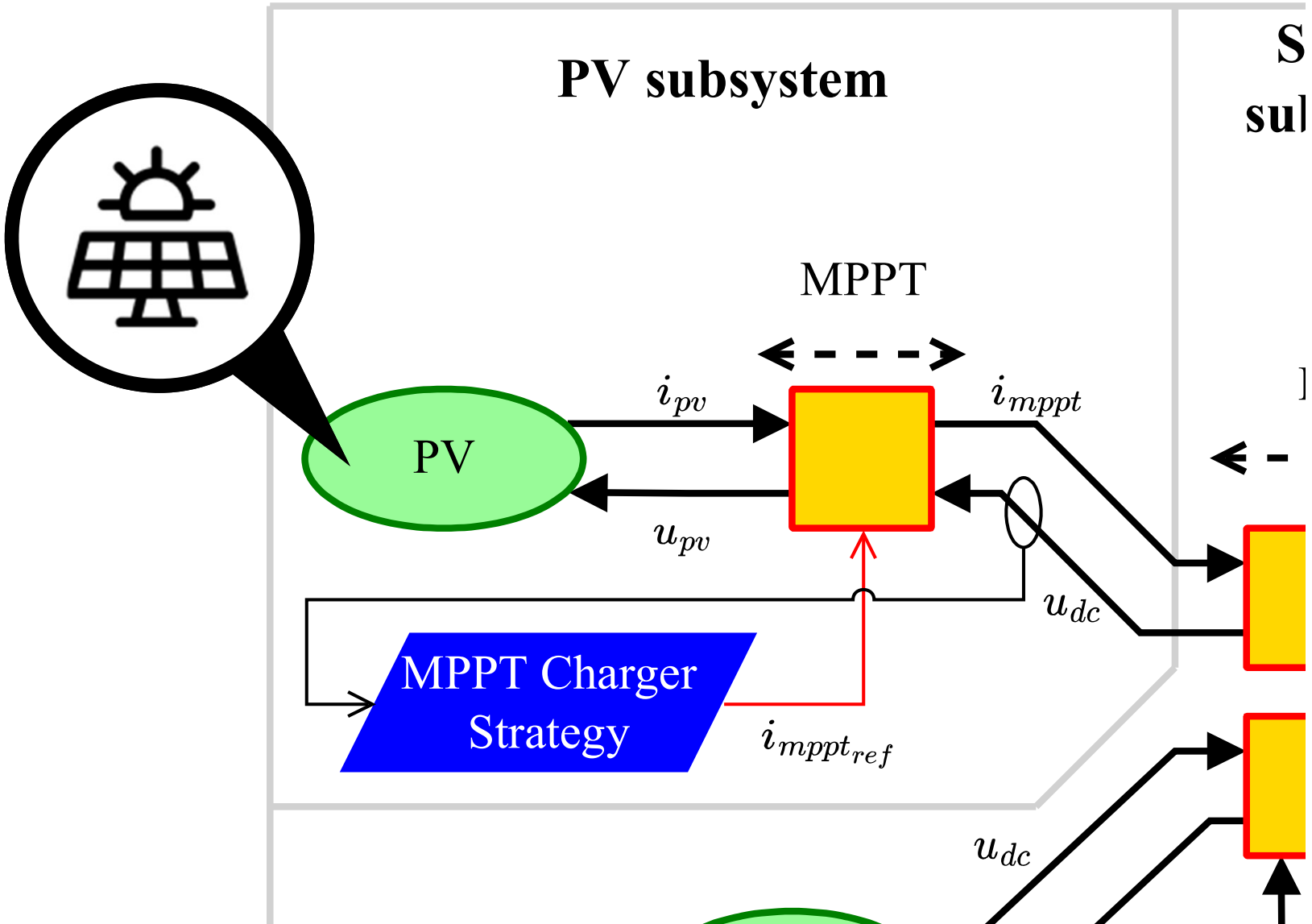
Outputs

- Fuel consumption (L)
- Diesel engine starts

Set points

- SoC_{min} (%)
- SoC_{max} (%)
- $Chrg_{rate}$ (%)


Storag
subsystem
AC subsy
MPPT
DC bus
Inv/Chrg mode
Charger
Gen coupling
Inv/Chrg mode
Generator
PV
MPPT Charger Strategy
Batteries
SoC
Inverter
DC-DC
AC load
DC load
AGS Strategy
Charger Strategy
AGS subsystem
DC load subsystem
i_{pv}
i_{mppt}
u_{pv}
u_{dc}
$i_{mppt_{ref}}$
u_{gen}
i_{gen}
$i_{chrg_{in}}$
$i_{chrg_{out}}$
$i_{load_{ac}}$
u_{ac}
i_{invch}
u_{inv}
$i_{inv_{in}}$
i_{bat}
u_{dcdc}
i_{dcdc}
i_{dcload}
$i_{chrg_{out_{ref}}}$
gen_{flag}
$SoC_{min_{th}}$
$SoC_{max_{th}}$
$chrg_{chrg_{rate}}$
1
2


PV subsystem
MPPT
PV
i_{pv}
i_{mppt}
u_{pv}
u_{dc}
MPPT Charger Strategy
$i_{mppt_{ref}}$
u_{dc}

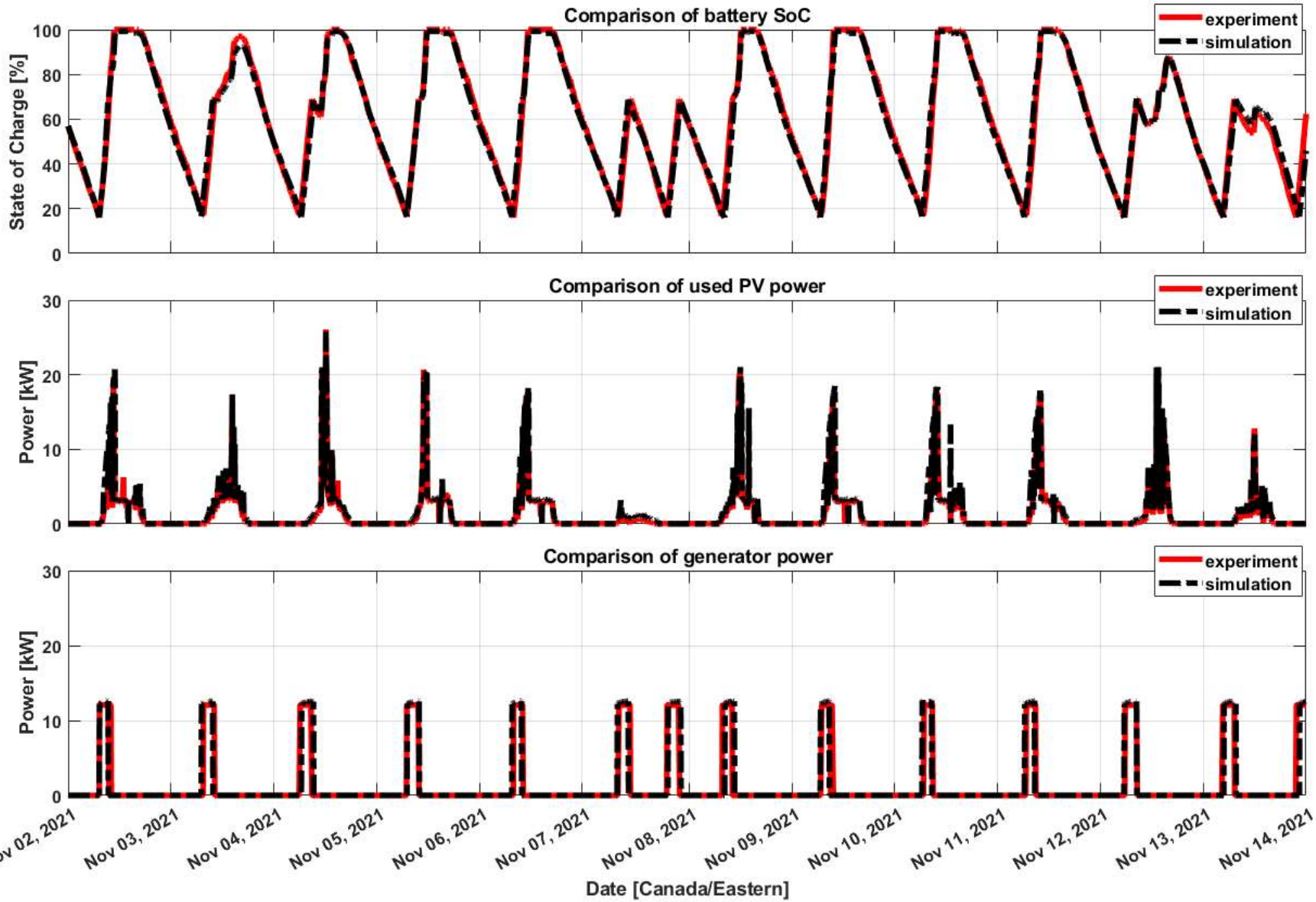
« Model Validation »

- Modeling comparison records: 2021-11-02 to 2021-11-14 -

NMAE: 2.2 %

NMAE: 1.6 %

NMAE: 2.1 %



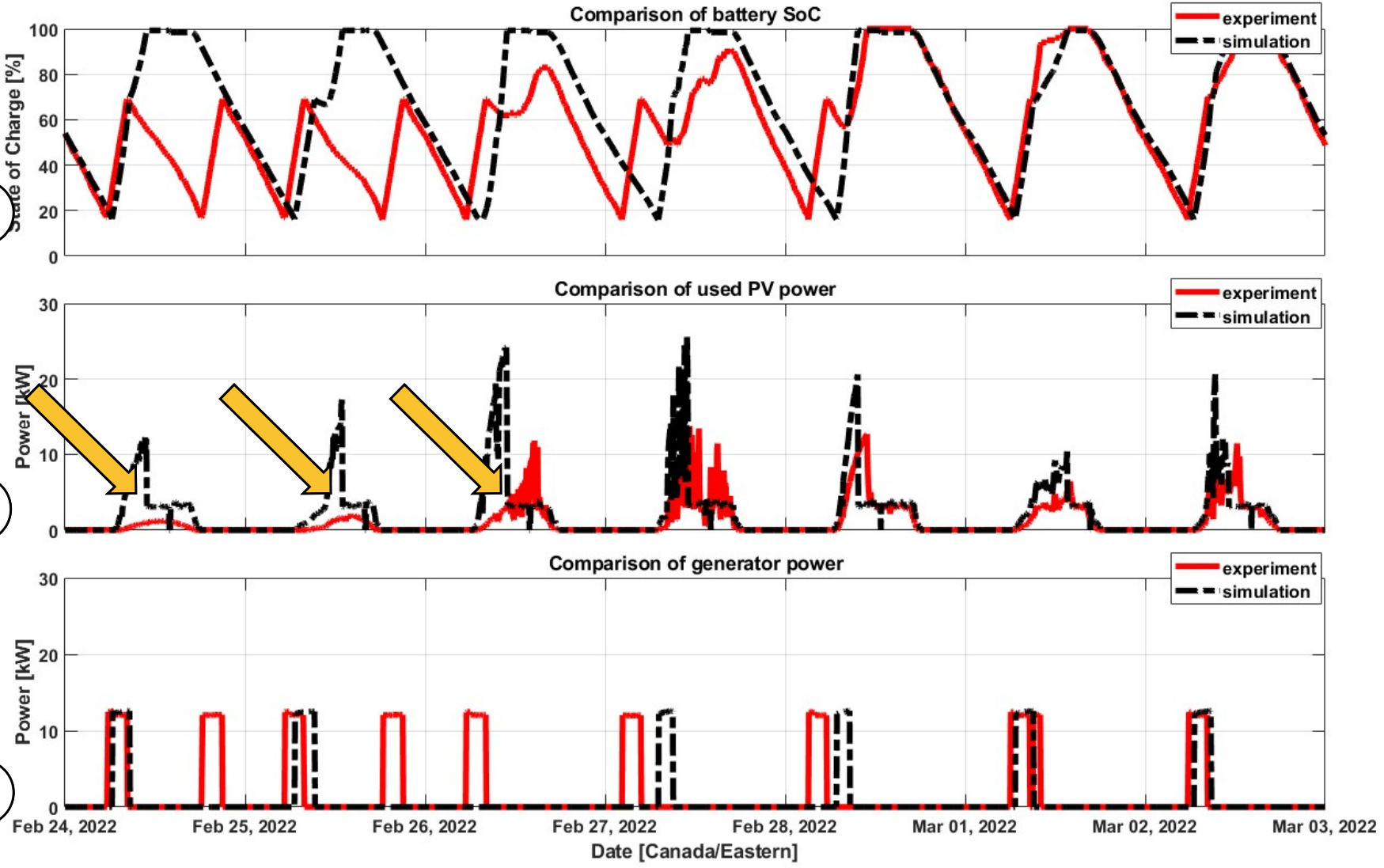
NMAE: Normalized Mean Absolute Error

- Modeling comparison records: 2022-02-24 to 2022-03-03 -

NMAE: 16.6 %

NMAE: 6.3 %

NMAE: 8.7 %



NMAE: Normalized Mean Absolute Error

- Snow Coverage -

The **snow coverage** on the PV array is a **limitation** of this model

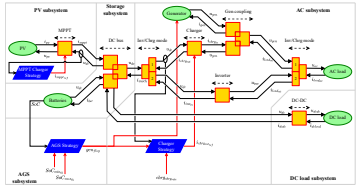
« Control Optimization »

- Optimization structure -

Timeseries inputs

- Temperature (°C)
- Irradiance (W/m²)
- Heaters power (W)
- Antenna power (W)

Model



Outputs

- Fuel consumption (L)
- Diesel engine starts
  - f_{DG}
  - N_{start}
- Cost (USD)

Generator cost equation [2]

$$c_{DG} = c_{fuel}\, f_{DG} + c_{start} N_{start}$$

c_{DG}: Generator usage cost [USD]

c_{fuel}: Fuel cost 1 USD/L

c_{start}: Start cost 2 USD

Set points

- SoC_{min} (%)
- SoC_{max} (%)
- $Chrg_{rate}$ (%)

Genetic algorithm

- Results for winter (2022-01-25 to 2022-03-20) -

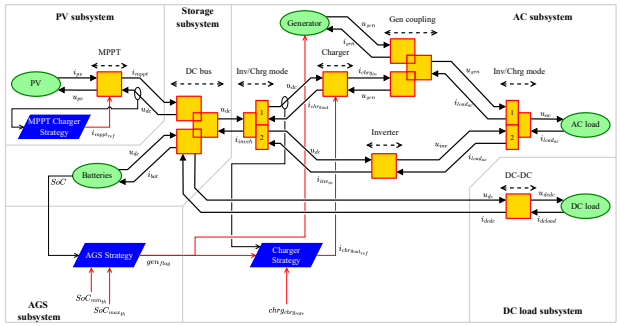
Timeseries inputs

- Temperature (°C)
- Irradiance (W/m²)
- Heaters power (W)
- Antenna power (W)

Fixed for optimization period

Winter

Model



703 **Outputs** 634

- Fuel consumption (L)
- 57 / 51 Diesel engine starts
- f_{DG} / N_{start}
- Cost (USD)
- 817 → - 10 % → 736

Genetic algorithm

SoC_{min} (%) | SoC_{max} (%) | $Chrg_{rate}$ (%)

Current set points: **16 %** | **70 %** | **100 %**

Optimized set points: **11 %** | **59 %** | **84 %**

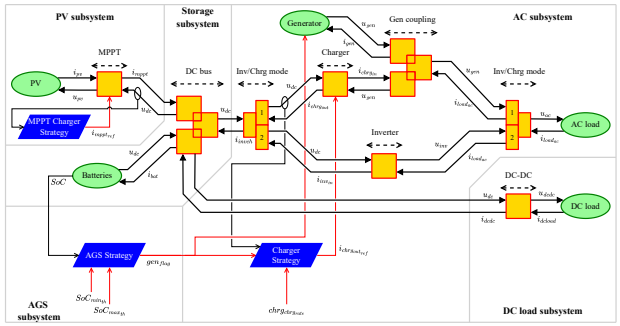
- Results for Spring (2022-03-20 to 2022-05-26) -

Timeseries inputs

- Temperature (°C)
- Irradiance (W/m²)
- Heaters power (W)
- Antenna power (W)

Fixed for optimization period
Spring

Model



306 Outputs **265**

- Fuel consumption (L)
- **26** Diesel engine starts **25**
- f_{DG} N_{start}
- Cost (USD)
- **358** - 12 % **315**

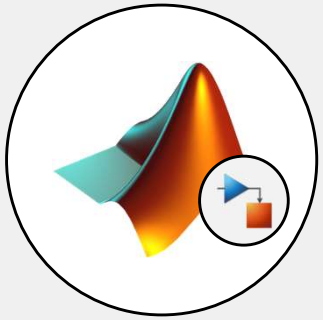
Genetic algorithm

SoC_{min} (%) | SoC_{max} (%) | $Chrg_{rate}$ (%)

Current set points: **16 %** **70 %** **100 %**

Optimized set points: **11 %** **46 %** **69 %**

- Improvement -



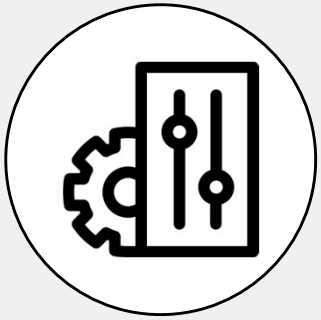
System modeling

Estimation errors:

Battery SoC: 2.2 %

PV power: 1.6 %

Generator power: 2.1 %



Control optimization

Generator usage cost:

Winter: -10 %

Spring: -12 %

« Conclusions »

- Contributions -

Modeling framework

Predictive scenarios

Optimized set points

- Perspectives -

Submodels improvement

Other period optimization

Other control algorithms

« BIOGRAPHIES AND REFERENCES »

- Authors -

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MSc. in Electrical Engineering at University of Sherbrooke (2023)
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