WP2: Network control, dynamic reconfiguration and load management

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RESCUES

WP2 Overview

Contributors: Imperial College London, IITKGP, IITD, UoS

Objective: Develop advanced coordinated strategies for energy management (EM) of the hybrid microgrid (HMG): optimization, control (voltage & frequency), load management and network reconfiguration.

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WP2 Overview

Key methodological steps:

- Identifying EM technical challenges and impact
- Developing robust optimization tools for operation and EM of the HMG
- Developing voltage and frequency control schemes
- Implementing state estimation-based network management system for on-grid/off-grid dynamic reconfiguration

Deliverables:

Energy management system & control schemes, and related software algorithms.

Work progress of Imperial College, Feb-Oct 2014

PDRA joined Imperial College team and RESCUES project in Feb 2014

First stage of RESCUES activity concentrated on literature review

Next stage focused the practical challenges in hybrid microgrid optimization and control

ICL activities

From review of state-of-the-art on hybrid microgrids (HMG)

Energy Management (EM) crucial for reliable and efficient steady-state performance by optimized use of available micro-sources. Widely explored for AC or DC MGs

However, globally, systemic and methodological study of EM issues and challenges in HMG configurations remain unpursued (very few publications, up to date).

Stand-alone MG operation can benefit of energy demand management schemes and energy storage embedded into EM systems.

Work progress of Imperial College, Oct 2014-May 2015

Development of an optimization (OPF) tool to be integrated into the energy management system (EMS).

First application: power balance analyses at the minimum cost.

Focus on:

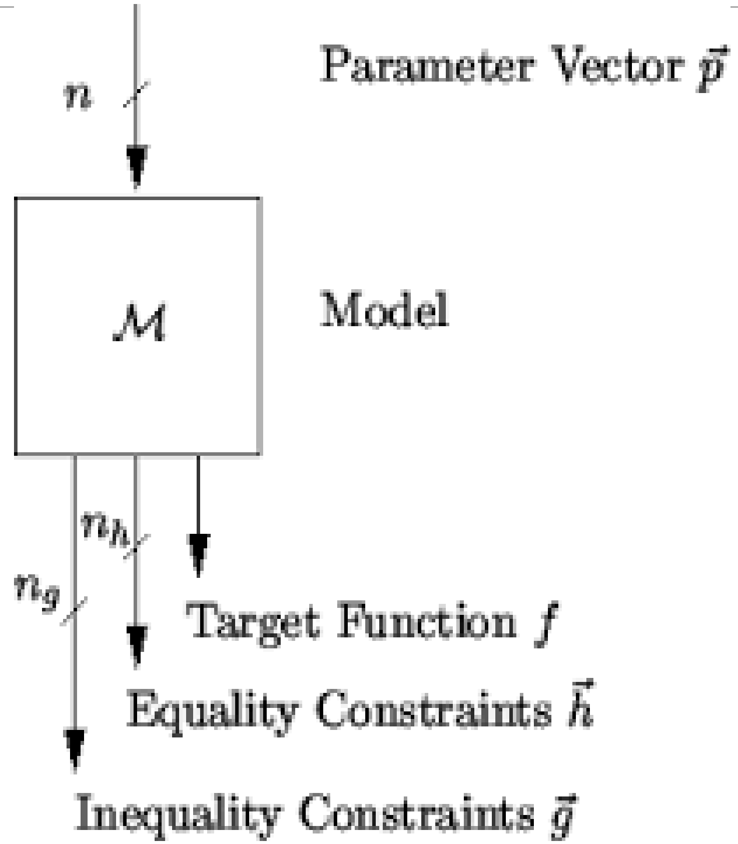
- the operation of the power exchange operated by the interlinking converter (ILC) between AC sub-MG and DC sub-MGs.
  - The ILC is modelled as an equivalent source of active and reactive power.
- The operation of the battery energy storage (BES) and the strategy of demand side management (DSM)

The OPF tool

Probabilistic: robust to present uncertainties (in renewable energy, load demand, etc...).

Flexible: suited to both security-oriented and cost effectiveness-oriented optimization.

First simulations address the problem of power balance in a hybrid microgrid at the minimum operation cost.

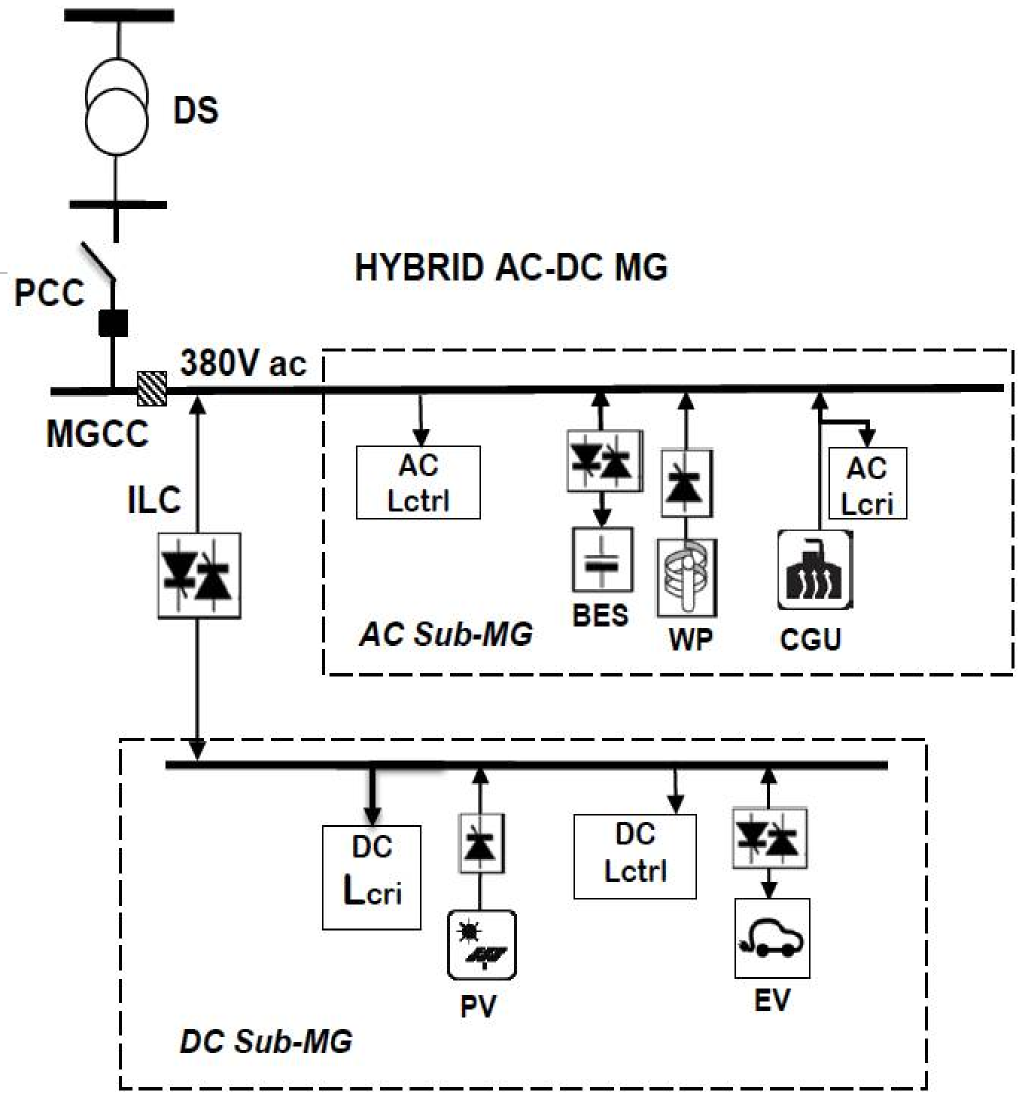


Case Study

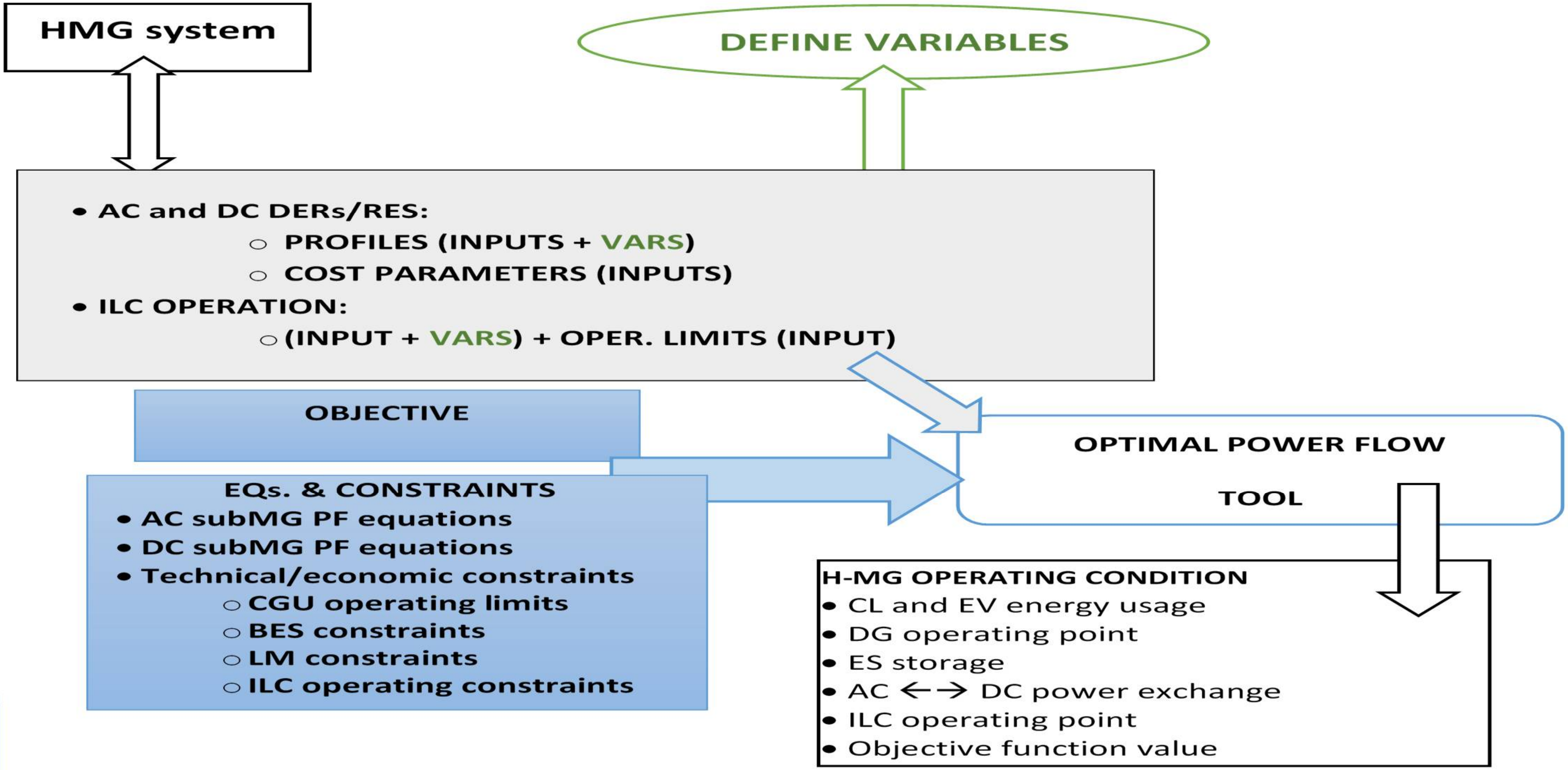
Off-grid hybrid microgrid (e.g. a coastal area)

Battery storage and demand side management on thermal loads and electric vehicles (EV) considered in the energy management scheme

Power production from renewables (PV and WP) and controllable generating unit (biomass, CGU)



How the OPF tool works within the Energy Management System



Problem: Cost-effective hybrid MG operation (1/2)

- Uncertainties considered on WP and PV dispatch, and on loads (both critical and flexible loads).
  - Modelled as probabilistic input power signals (power versus time) via combined Monte Carlo Simulation (MCS) and Scenario Reduction (SR).
- ILC modelled as an equivalent power injection AC-to-DC or vice-versa, because focus is on ILC contribution to system-level power balance.
- All power electronics interfaces (ILC and DERs links) are considered working at $\phi = 0$ (so, reactive power component Q=0)

Problem: Cost-effective hybrid MG operation (2/2)

OPF formulation customized to assessing total costs of optimal hourly operation of the HMG

A) **Base case:** full availability of HMG resources:

- Max CGU power output is 500 kW
- BES charge/discharge supporting power balance
- DSM (load shedding): flexible loads 50% controllable; EVs 75% controllable
- Max ILC transfer capability 1.5 MW

Other cases:

B) halved CGU capacity (max 250 kW),

C) w/o BES support,

D) parametric analysis of ILC transfer capability (1MW and 500kW)

E) EVs controllability reduced up to 40%

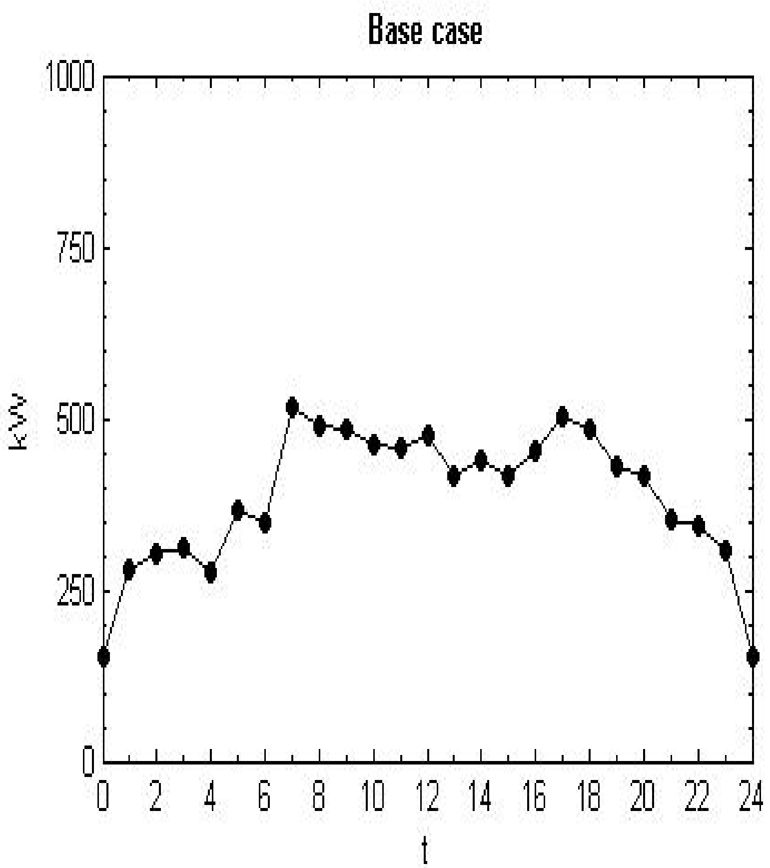
Results: impact of battery storage (BES) operation

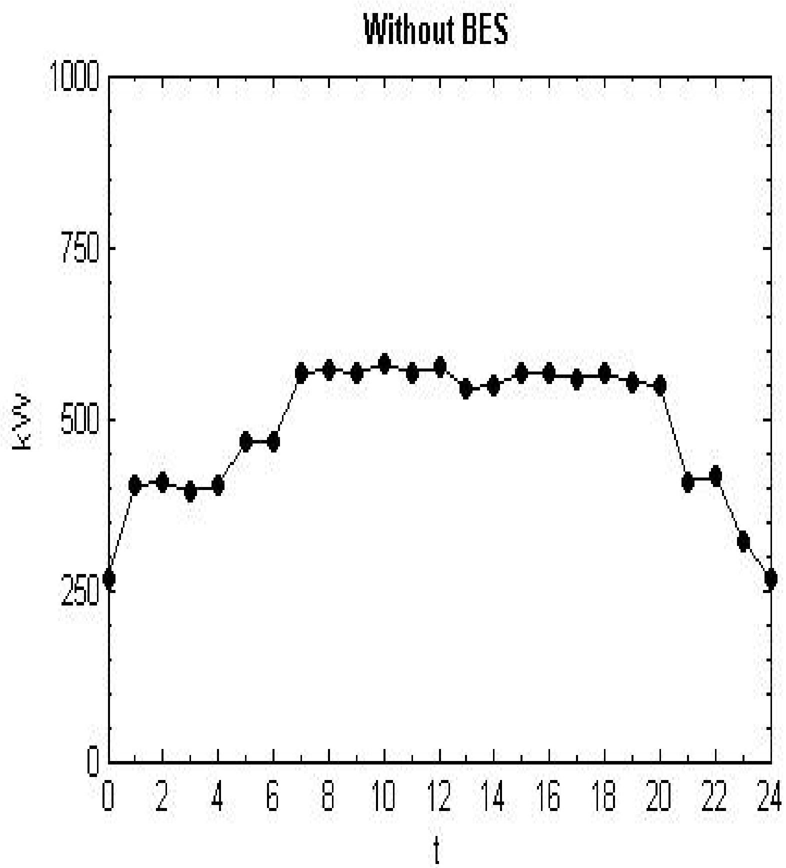
Importance of battery storage (BES) integration into the energy management system (EMS)

If the EMS does not integrate BES (case C), power balance requirements call for

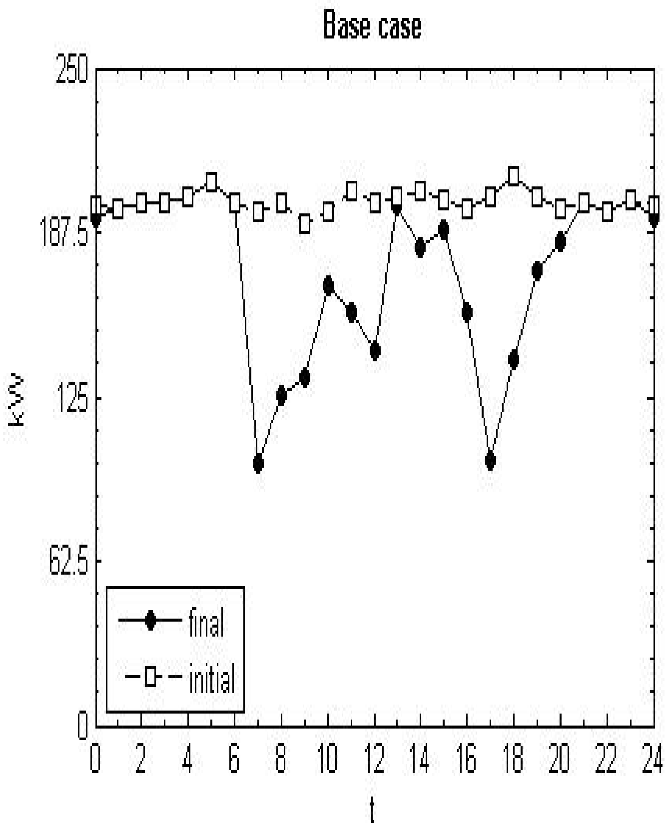
- a significant reduction of the demand from flexible loads (in peak hours) and EVs (overnight)
- Enforcing the ILC to transfer more power from AC sub-MG to DC sub-MG, during day time, working closer to limits (stressed conditions)

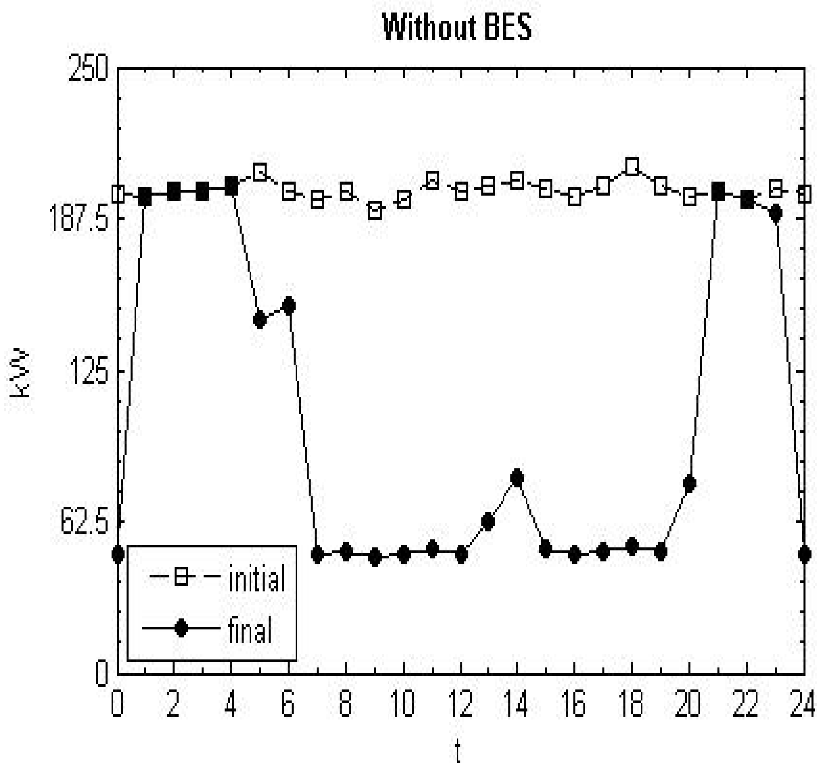
No BES support forces higher ILC power transfer during daytime





No BES support increases load shedding (e.g., in AC sub-MG)





Results: impact of interlinking converter (ILC) size on hybrid microgrid (HMG) operation (1/2)

The ILC transfers power from AC sub-MG to DC sub-MG, always! This is because the DC sub-MG is weaker and thus calls for support from the AC sub-MG resources

Different ratings (500kW, 1MW, 1.5MW) do not yield changes in the operational program of the HMG resources.

However, a rating < 500kW yields infeasibility of the optimization problem.

Finally, different sizes of the ILC do not impact on the costs of the HMG operation.

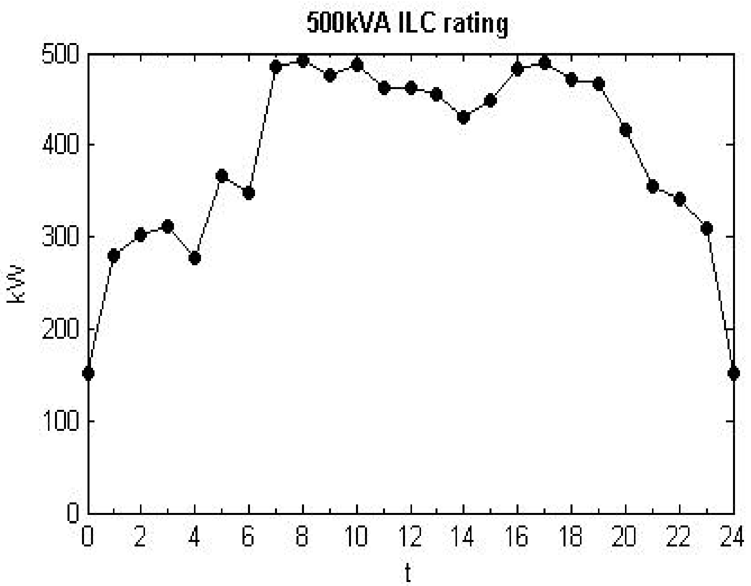
Results: impact of interlinking converter (ILC) size on hybrid microgrid (HMG) operation (2/2)

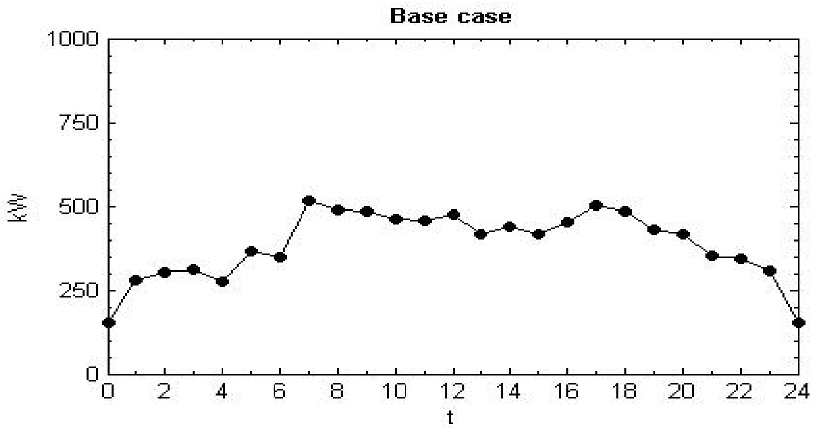
Flexibility of OPF (suitability in different stages of analysis)

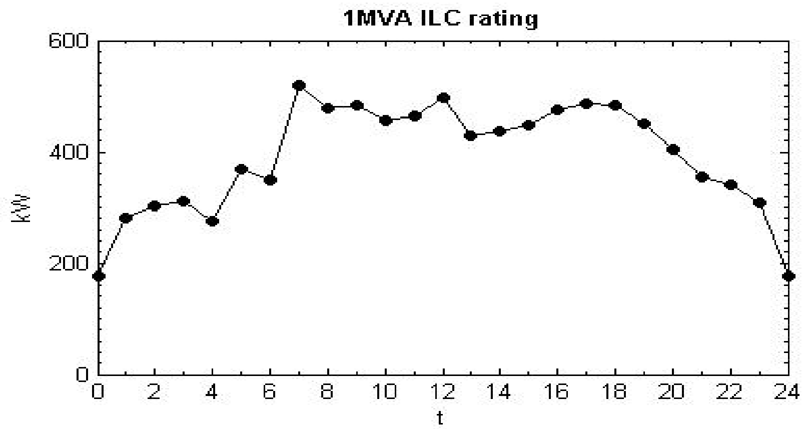
Running the OPF tool has then provided important information on the optimal size of the ILC device (typical planning problem).

In fact, it suggests that a 500 KW size is optimal in reliability terms (allows HMG operation with a good degree of resources performance), and in monetary terms (allows saving on initial investment costs as well as on future maintenance costs).

ILC power transfer from AC subMG to DC subMG does not change for lower ILC rating (500kW)







Results: impact of controllable generating unit (CGU) on HMG operation

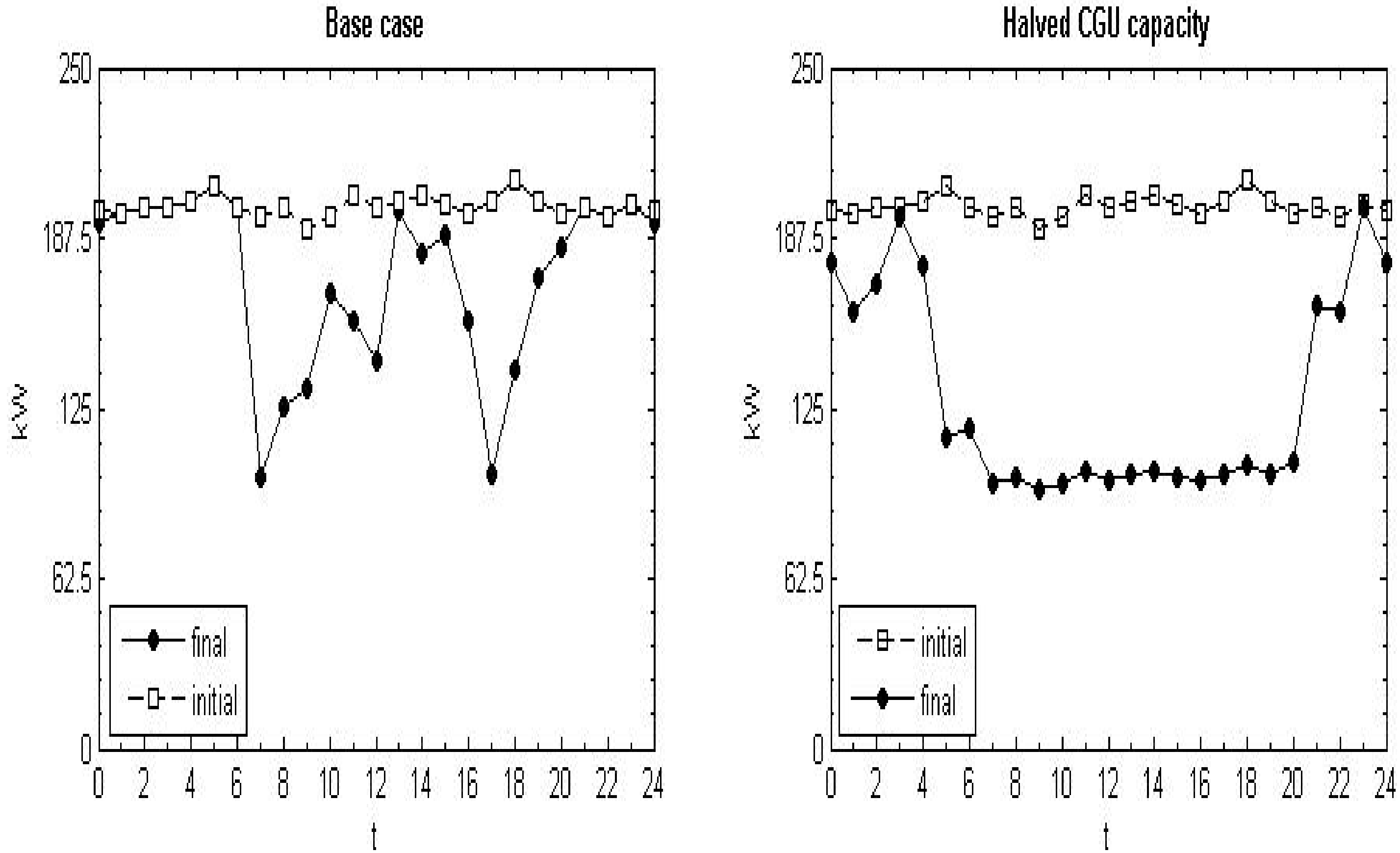
The CGU mostly works at full capacity (450-500 kW), because it was chosen as the cheapest resource.

When CGU capacity is halved (case B, max 250 kW), the energy management system (EMS) calls the demand side management (DSM) scheme to increase load shedding on flexible loads and electric vehicles (EVs).

If DSM were not included in the EMS, or if flexible loads and EVs had limited controllability (such as in case E)), the flexibility of the HMG operation and the reliability of the power supply to the customers would be significantly decreased.

Impact of CGU on load shedding (AC sub-MG)

Increased load shedding during daytime



Conclusions (1/2)

The first methodological contribution from Imperial College to WP2 of RESCUES project are an energy management scheme (EMS) and an optimization tool (OPF) for the efficient and reliable operation of remote hybrid microgrids (HMGs).

The operation of the hybrid MG relies on battery storage (BES) and demand side management (DSM).

The OPF is flexible, i.e., adaptable to different problems and stages of analysis.

Conclusions (2/2)

In steady-state studies oriented to global power analyses, the interlinking converter (ILC) can be modeled through its active/reactive power injections.

This representation could not work in more control-oriented and dynamic studies, where detailed model of power and voltage control of the ILC could be required.

Future work will address alternative ILC models based on study/development requirements.

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Remarks

Modeling method strictly depending on:

- the case studies selected for RESCUES, in terms of topology, configuration and organization of HMGs (remote, isolated, weakly connected,...?)
- the operation control strategy and energy management criteria of each of these cases.

In other words, energy management and optimization studies assumes the availability in RESCUES of preconditioning outputs dealing with stability and security analyses. These outputs (specifications from WP1) should be used as basic reference to model the HMG systems and properly identify variables and constraints.