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RESCUES
Reliable and Efficient Solutions for Community Energy Systems

1st Review Meeting

Feb 11, 2015 – University of Exeter

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WP2: Network control, dynamic reconfiguration and load management

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WP2 "Network control, dynamic reconfiguration and load management" – General overview

Contributors: Imperial College, IITKGP, IITD, UoS

Objective: Development of advanced coordinated strategies for optimization, control, management and dynamic reconfiguration of the hybrid MG.

Key methodological steps:

- Study of issues and associated effects on system operation
- Development of robust optimization tools for the operation and management of the hybrid MG
- Development of voltage and frequency control schemes
- Implementation of state estimation-based network management system for on-grid/off-grid dynamic reconfiguration and load management

Deliverables:

Network management and control schemes, and related software algorithms.

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Where ICL was…

- PDRA joined ICL team and project in Feb 2014
- First stage of RESCUES activity concentrated on literature review
- Envisaged next stage was focusing the **practical challenges** in hybrid microgrid optimization and control

Where ICL is now… (1/2)

- **Results of review of state-of-the-art on** hybrid microgrid (HMG) optimization and control
  1. **Energy Management (EM) crucial** for stable, economic and secure steady state performance through optimized use of the available micro-sources. Widely explored for AC or DC MG configurations
  2. Methodological platform for **HMG control widely covered** in recent years (e.g., Uni. of Aalborg)
  3. However, globally, **systemic and methodological study of EM** issues and challenges in HMG configurations **still unpursued** (very few publications, up to date).
  4. Stand-alone MG can benefit of **load management (LM)** schemes and **energy storage (ES)** embedded into EM systems for schedule compliance.

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Where ICL is now... (2/2)

First methodological development in the direction of designing EM systems (EMS) for stand-alone hybrid MGs.

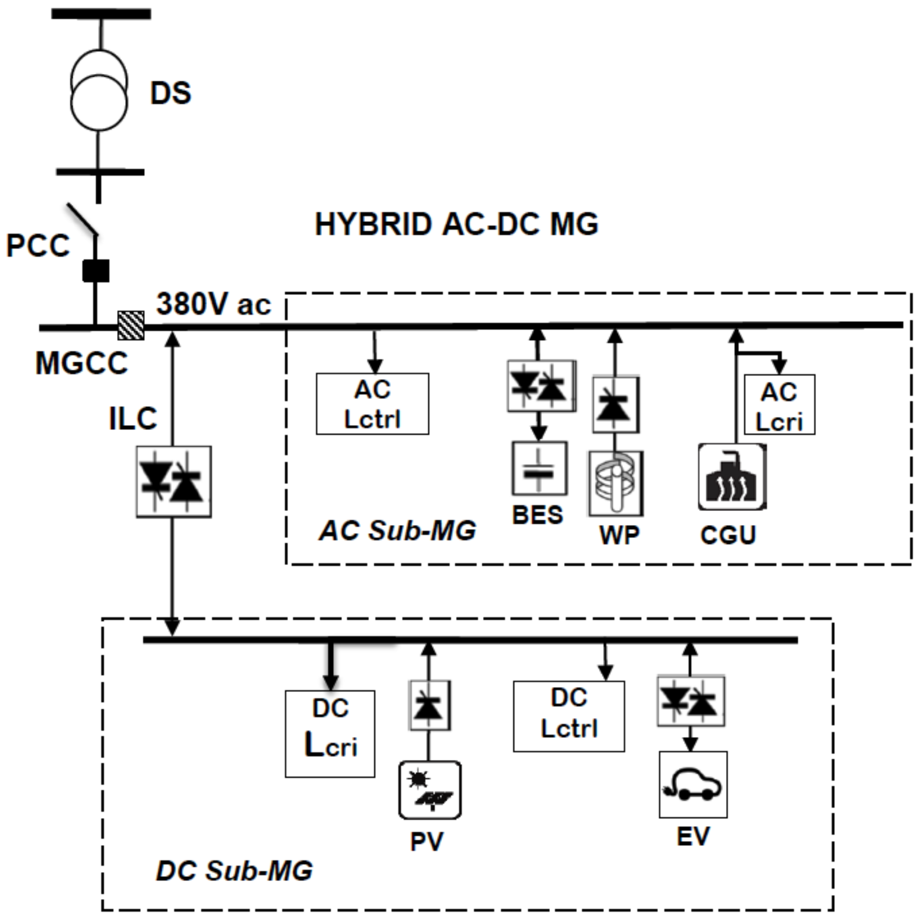
- **Development of a novel approach for optimal operation or operational planning of hybrid MG systems**

- **Development of a flexible OPF tool suitable for integration into EM system and capable to assess the optimal strategy of use of HMG resources**
  - **Features:**
    - *the tool is based on probabilistic algorithm to make assessments robust to possible uncertainties (renewable energy, load demand, etc...)*
    - *all system components, functions and interactions are represented via proper mathematical models*

- **First simulations focus on the objective of power balance at the minimum operation cost.**

Applicative Case study: Optimal operation and operational planning of hybrid microgrid

Ref. to a generic but realistic configuration of HMG (coastal area)



- **Input database referred to energy, load and demand reports/archives**
- **Focus on:**
  - **LM on controllable loads and Evs** to adjust demand for compensating RESs supply fluctuations
  - **Potential of battery energy storage** for schedule compliance.
  - **ILC operation** and correspondent power exchanges between AC sub-MG and DC sub-MG, in relation to the RESs behaviour.

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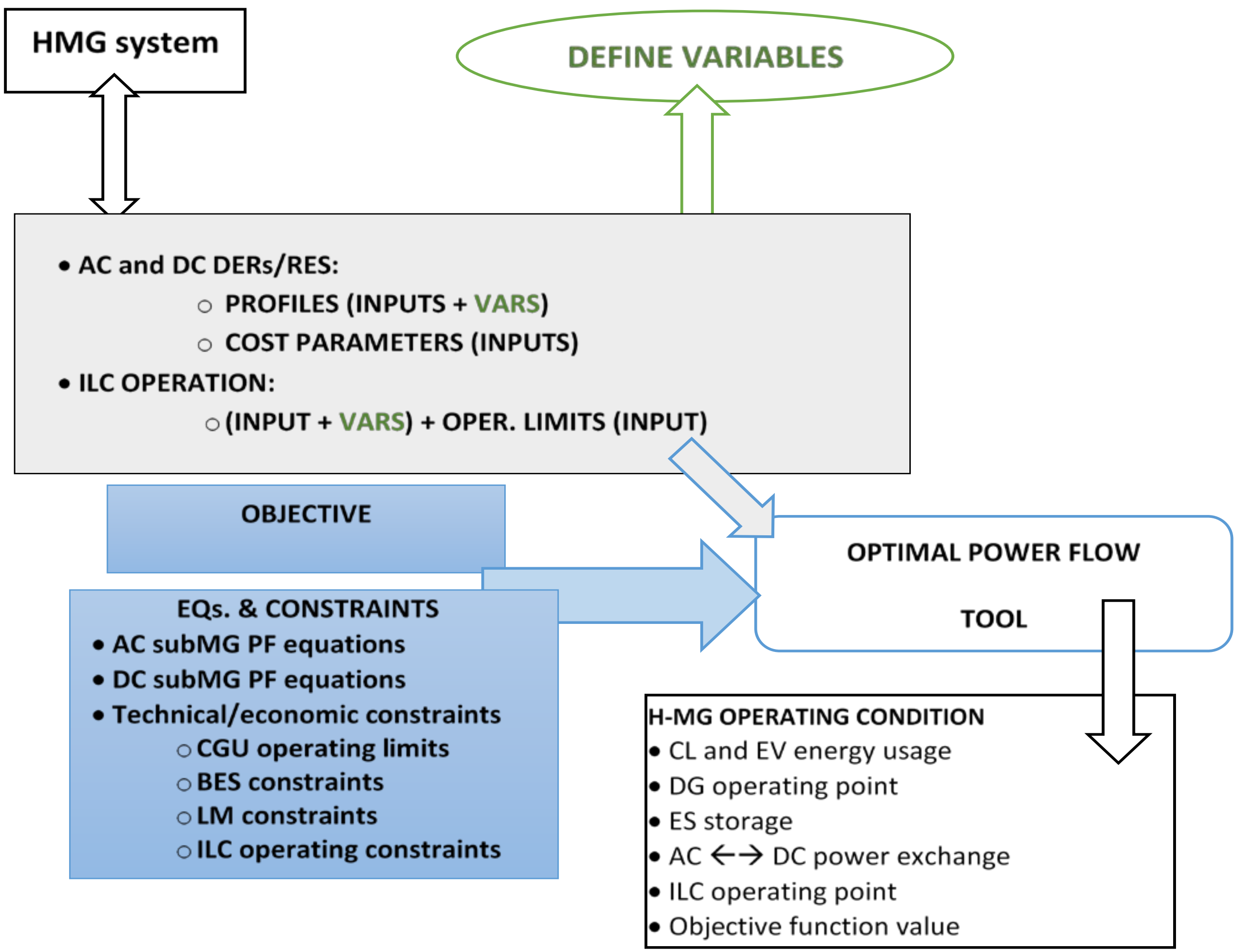
OPF tool

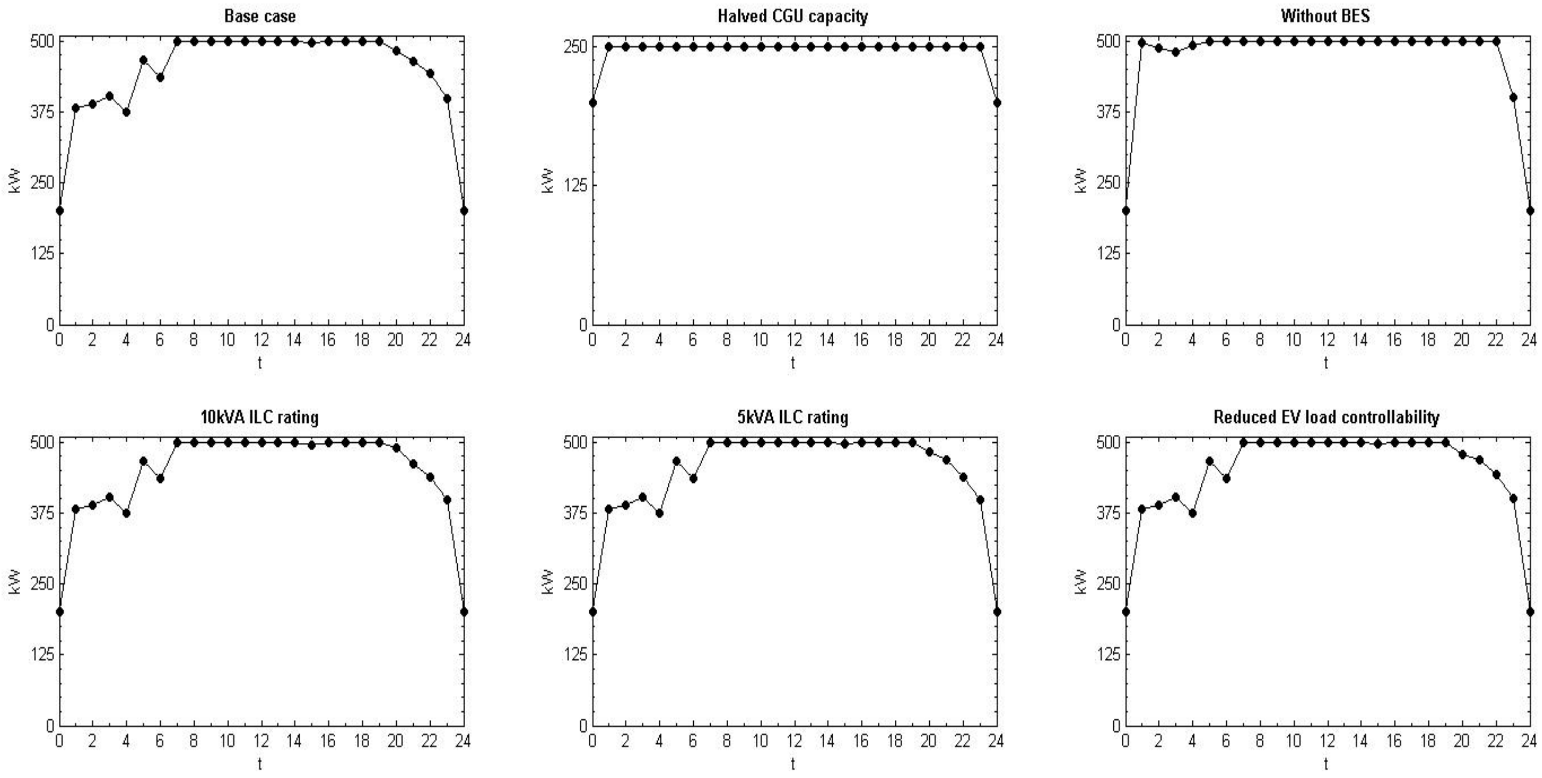


1° Case study: Cost-effective operation of HMG

- **OPF formulation customized for assessment of total costs of optimal daily (24-h) operation**
- **In a base case**, operation regards all manageable ("controllable") energy services and resources within the selected HMG structure:
    1. power production from CGU
    2. Support to schedule compliance via BES charge/discharge
    3. Shedding-based LM on controllable loads and Evs
    4. ILC operation for power transfer from AC to DC and vice versa
- **Other cases** simulate other possible scenarios/compositions (w/o BES, different CGU, LM scheme, AC/DC power transfer capabilities)
- **Uncertainties on RESs dispatch and load** (critical/controllable) demands.
    - Loads and RESs represented as probabilistic input power signals (power versus time) modelled via combined MCS - SR techniques.
- **ILC** modelled **as equivalent power injection** AC-to-DC or vice-versa , as focus is on its contribution to power

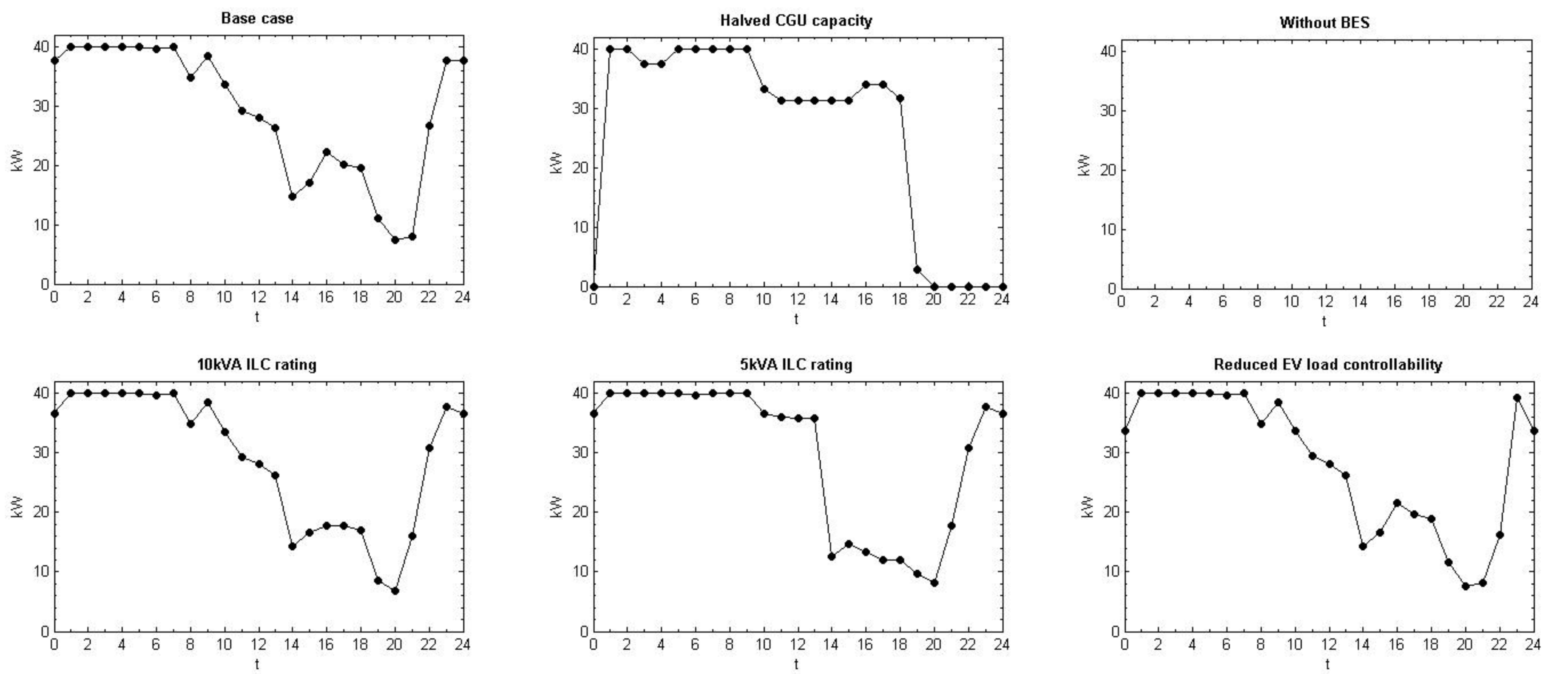
Some results:

CGU dispatch



Some results:

BES available capacity over 24-hs



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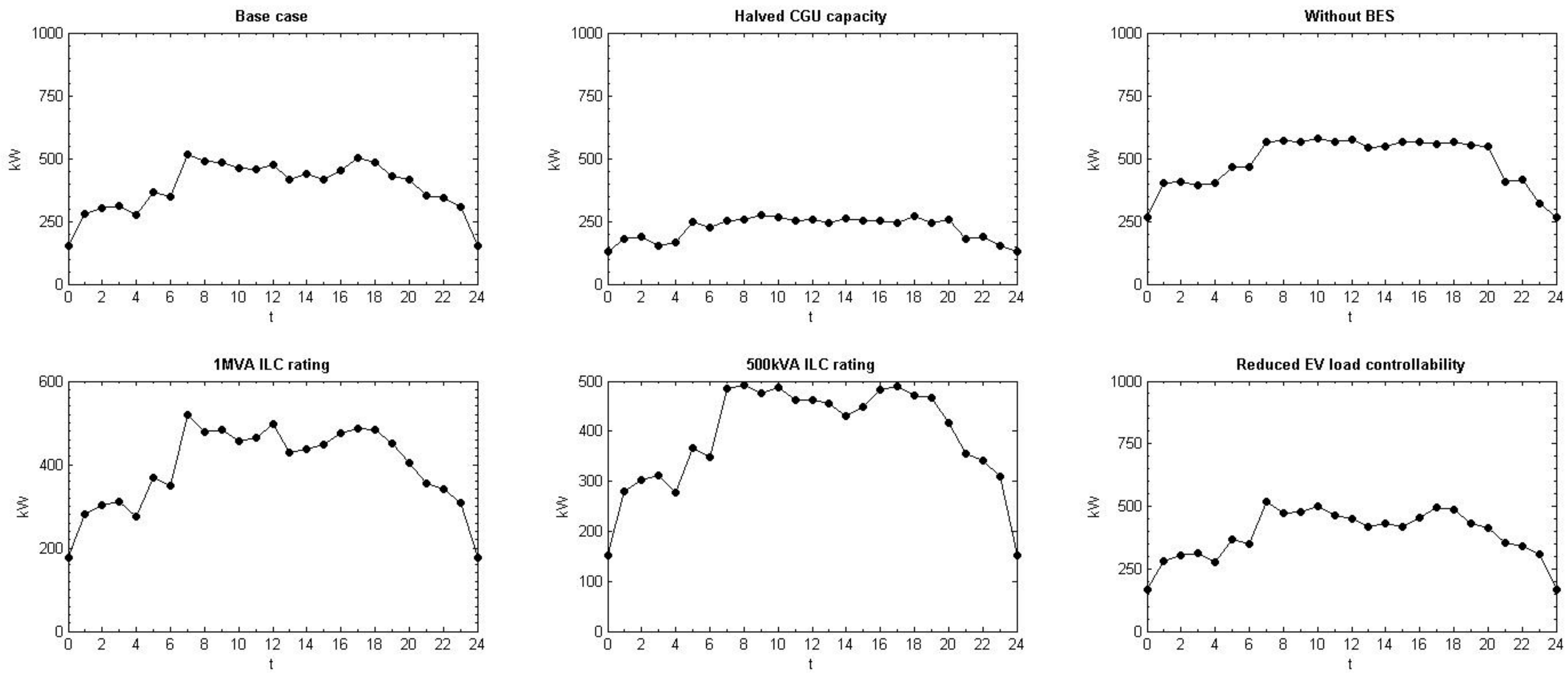
Some results:

ILC power transfer from AC subMG to DC subMG



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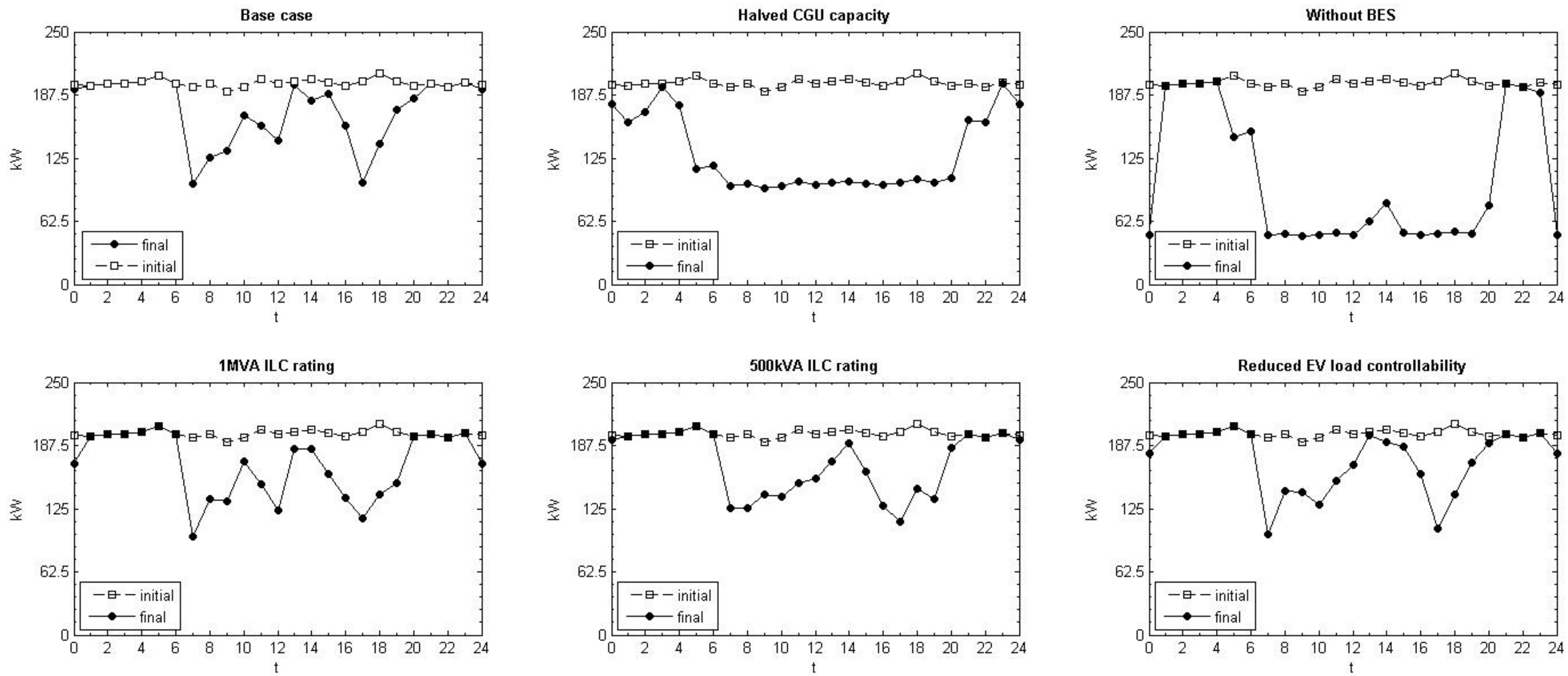
Some results:

Controllable load (AC side) before and after LM



Criticalities

- Internal research/development activity:
  - Criticalities met: typical of similar cases (modelling and methodological platform)
  - Criticalities expected:
    - Modelling/methodological focused and ready for being addressed
    - Keeping-up with state-of-art
    - Control of process and delays

- External:
  - Control of process
  - Control of interactions
  - Budget

Thank you
for
your attention

We welcome your questions, suggestions, comments

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The RESCUES Project and Consortium

Reliability and Efficient System for Community Energy Solutions (RESCUES) is a medium size Academia-Industry partnership aimed at developing *smart grid (SG) with optimum sensible storage solutions* for rural communities across UK and India.

Academia

UK:

- *Imperial College London (ICL)*
- *University of Exeter (UoE)*
- *University of Strathclyde (UoS)*

India:

- *Indian Institute of Technology, Madras (IITM)*
- *Indian Institute of Technology, Kharagpur (IITKGP)*
- *Indian Institute of Technology, Delhi (IITM)*
- *Delhi Technological University (DTU)*
- *Visvesvaraya National Institute of Technology (VNIT)*

Industrial Partners:

- *ABB*
- *Alstom*
- *Bowman Power*
- *EON*
- *GE*

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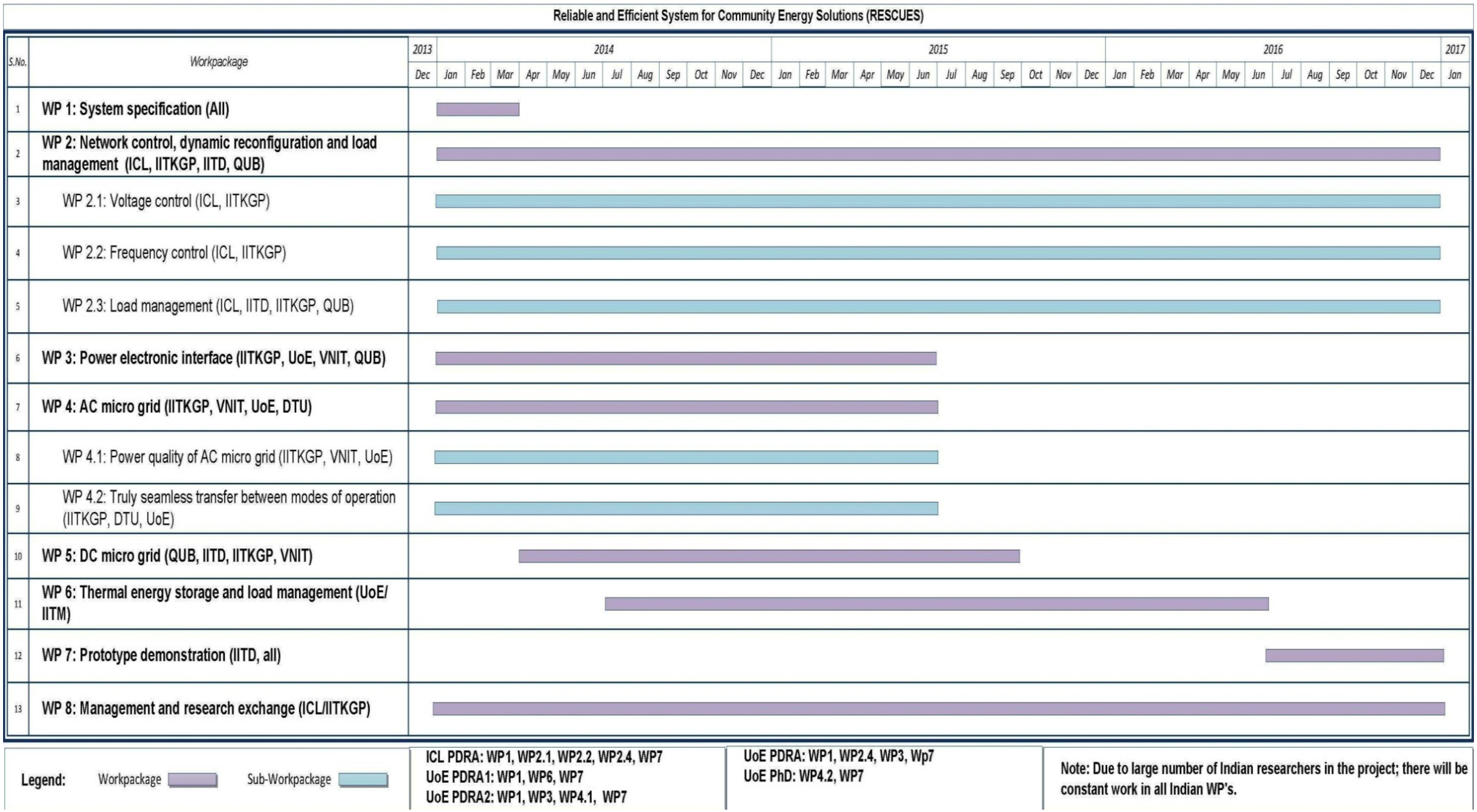
Work Packages Overview and Original Time Plan



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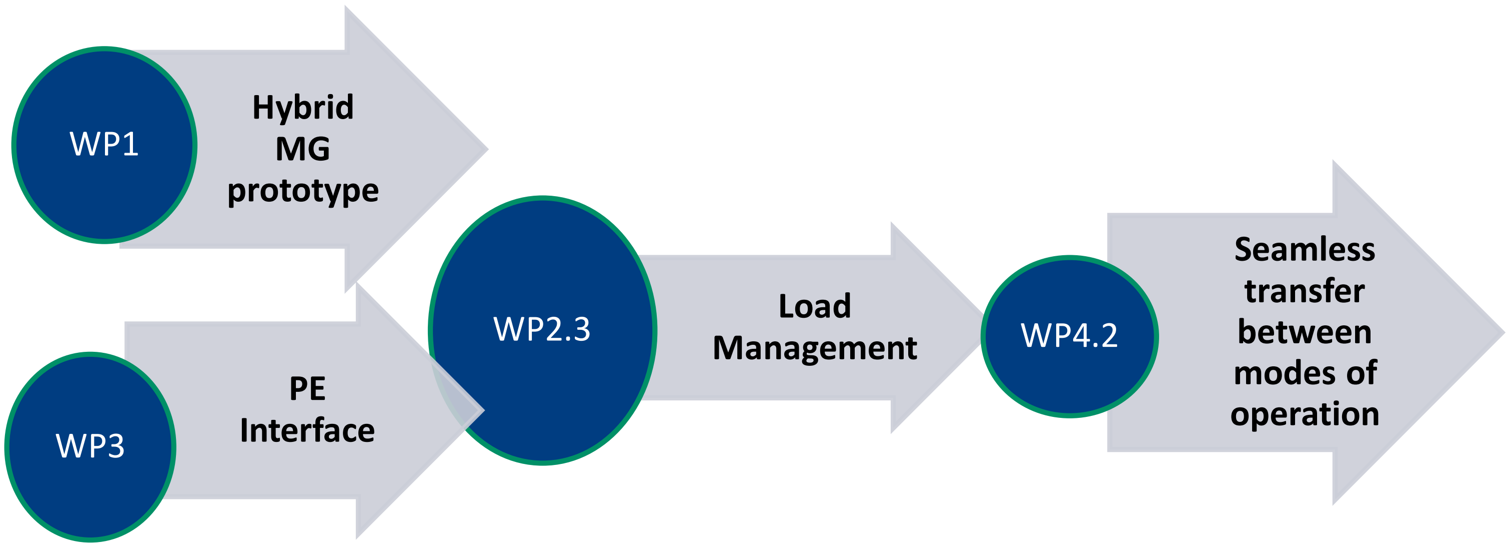
Identified interactions between WP2 and other WPs



WP2.1: Voltage control (1/2)

Contributors: ICL, IITKGP

Motivation:

- Voltage stability crucial aspect in MG control
- Low voltage levels and uncompensated loads put system at risk for voltage instability and collapse
- Power electronic converters-based voltage stabilisation critical, especially in MG's islanded mode

Objective:

Design of advanced, robust voltage control strategies to optimise voltage regulation capabilities

- ➢ Focus interactions among different MGs' distributed resources (energy sources, converters, loads, control devices).

Deliverable:

A software algorithm to be run on the control center, regulating voltage control settings based on predicted/measured generation and load.

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WP2.1: Voltage control (2/2)

Methodology:

1. State-of-the-art review
   a) Literature on voltage control methodological platform
   b) Particular interest on latest technologies and techniques
   c) Assess suitability for RESCUES system

2. Methodological platform reduction and enhancement
   a) Extraction of most suitable technologies and methods from existing platform
   b) Assess adaptability of selected methods to RESCUES case studies
   c) Refinement or new proposal

3. Final algorithm envisaged as an optimisation model for coordinated cooperative control of resources

WP2.2: Frequency control (1/2)

Contributors: ICL, IITKGP

Motivation:

- Due to operation mode transfer and intermittency of some DG, frequency deviation caused by active power deficiency often occurs in islanded MGs
- Islanded MGs are autonomous systems with small equivalent inertia, which makes frequency control more difficult than for conventional grids
- Need of keeping frequency conform to energy quality standards, no matter the changes in load or other disturbances

Objective:

Design of advanced frequency control mechanisms for off-grid operation of the MG.

Deliverable:

An algorithm to be run in central distribution management system (DMS), allocating decentralised voltage reference set point commands.

WP2.2: Frequency control (2/2)

Methodology:

1. State-of-the-art review
   a) Literature on frequency control methodological platform, particularly latest advancements
   b) Assess suitability for RESCUES system

2. Methodological platform reduction and enhancement
   a) Extraction of most suitable methods from existing platform
   b) Assess adaptability of selected methods to RESCUES case studies
   c) Refinement or new proposal

3. Algorithm
   a) frequency regulated through re-setting of power electronic converters, on-load tap changers (OLTC), energy storage-network power electronics interface, etc.
   b) Sensed rate of fall in frequency commanding change in voltage-sensitive demand and corresponding change in voltage

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WP2.3: Load management (1/2)

Contributors: ICL, UoS, IITKGP, IITD

Motivation:

- MG transfer from on- to off-grid operation impacts on distribution network reconfiguration
- MG optimal capacity and optimal network reconfiguration with minimal losses are key issues

Objective:

Design of network management system for:

- Load management during on/off grid operation
- Dynamic network reconfiguration

Deliverables:

A state estimation-based management scheme, for optimal management of loads and on-grid/off-grid network reconfiguration.

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WP2.3: Load management (2/2)

Methodology:

1. State estimation-based approach, with inputs from DG, feeder flows, loads
2. Use of “already-set up” ICL’s state estimator approach for distributed networks, extended to unbalanced systems
3. Approach enhanced for fast connection between AC and DC sub-MGs, with proper synchronisation