Transforming Low Voltage Networks Into Small Scale Energy Zones

• Microgrids Symposium
• Professor Phil Taylor
• Durham University
Overview

• Durham University/Energy Institute
• Small Scale Energy Zones
• Methodology
• Control Requirements
• Control Approach Selection
• Simulation Results
• Practical Results
• Conclusions
• Further Work
Durham University

• Chancellor Bill Bryson
• Founded in 1832
• Collegiate University
• 15,000 students
• Ranked 5th in UK

• Engineering (Unified Approach)
• Ranked 3rd in UK
• 500 Undergraduates
• Research Groups Energy, Mechanics
Durham Energy Institute

• ‘Science and Society’

• 10 Departments (Engineering, Physics, Earth Sciences, Anthropology)

• Multi-disciplinary

• £36M Energy Funding last five years
Small Scale Energy Zones
Methodology

- Micro-generation Growth
- Network Models
- Laboratory Design and Development
- Impact Studies (Passive, Grid Connected)
- Define Control Requirements
- Control Approach Selection
- Controller Implementation (Simulation and Lab)
- Controller Evaluation
SSEZ Control Requirements

- Overcome Network Constraints
  - Voltage Limits
  - Voltage Unbalance
  - Thermal Limits
  - Reverse Power Flow Limits

- Achieve Operational Goals
  - Zero Export
  - Zero Import
  - Self Sufficiency
  - Constant power import
  - Dispatchable power output
Network Models

- Low voltage
- UK Generic
- EU Generic
- Real UK
- Steady state 3 wire
- Dynamic 4 wire
- Validated with UK DNOs
Generic UK/EU and Real UK Networks
Impact Studies

<table>
<thead>
<tr>
<th></th>
<th>UK</th>
<th>EU</th>
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<tbody>
<tr>
<td><strong>Voltage Regulation</strong></td>
<td>770</td>
<td>325</td>
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<tr>
<td><strong>Voltage Rise</strong></td>
<td>185</td>
<td>535</td>
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<td><strong>Voltage Unbalance</strong></td>
<td>47.8/ph</td>
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<td><strong>Transformer Thermal Limits</strong></td>
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<td>505</td>
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<td><strong>Cable Thermal Limits</strong></td>
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<td>340</td>
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<tr>
<td><strong>Increase in Losses</strong></td>
<td>80</td>
<td>180</td>
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Table 1: Allowable SSEG volumes [kW] for the UK and European generic network.
Laboratory Development

• **Requirements**
  – Assess the impact of micro-generation on distribution networks.
  – Validate models.
  – Implement, test and refine the control algorithms developed during research programs.

• Network 4 wire
• Load (single phase)
• Generation (single phase)
• Energy Storage (single phase)
• Instrumentation
• Controllability (Repeatable Tests)
Experimental SSEZ
Schematic Layout
Data Acquisition
Control Approach Selection

• Centralised versus Distributed?

• Criteria
  – Scalability and Openness
  – Efficient Communications
  – Resilience and Reliability

• Attributes
  – Autonomy
  – Social Ability
  – Reactivity
  – Pro-activeness
Envisaged Implementation
Controller Evaluation- Simulation

- MAS approach
- FIPA Compliant
- Jade My SQL
- Link to PSCAD
MAS Implementation
Simulation Results

![Graph showing simulation results for different feeders over time.](image-url)
Controller Evaluation - Laboratory

Figure 6: Operation of over-voltage agents in the Experimental SSEZ.
Controller Evaluation - Laboratory

Figure 7: Generation output of (a) PV generator and (b) Wind Turbine Generator during operation of overvoltage agents on Experimental SSEZ.
Controller Evaluation - Laboratory

Figure 6: Effect of agent deployment in undervoltage conditions
Controller Evaluation - Laboratory

Figure 7: Effect of agent deployment in overcurrent conditions
Conclusions

• SSEZ Concept
• Simulation and Laboratory Developments
• Distributed Control Approach - MAS
• Evaluated through Simulation and Laboratory
• Encouraging results