Potential Solutions to Mitigate the Impacts of LCT

Appendix K

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Outline

- Objectives
- Problem Description
- Mitigating actions
  - Loop Connection
  - OLTC
  - Energy Storage
- Economic Comparison
- Conclusions
Objectives

- **Project objective:**
  - Understand the characteristics, behaviour, and future needs of Low Voltage Distributions Networks with high penetration of low carbon technologies.

- **Research objective:**
  - Maximise the penetration of low carbon technologies minimising the impacts on LV networks.

- **Presentation objective:**
  - Proposing possible mitigating actions for increasing the penetration of LCT in LV network in a stochastic framework.
Problem Description: Introduction


- Requirements for solving the problem:
  - Monte Carlo analysis to cope with the uncertainty (LCT size and location, sun profile, heat requirements, EV utilization, load profile, etc.)
  - **Time Series** Analysis – 5 min synthetic data.
  - Three-phase **unbalanced** power flow – OpenDSS.

- Inputs data:
  - Load and LCT **profiles**.
  - Real UK **networks** (topology and characteristics).
Problem Description: Methodology

This process is repeated 100 times for each feeder and penetration level (% of houses with PV panels).

- **Random allocation for each customer node.**

- **Random allocation of sites and sizes.**

- **Time Series Simulation.**
  - 3 Phase four wire power flow

All the solution are implemented in each simulation.
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Mitigating Actions

- Can we decrease the impacts of LCT on LV distributions networks?
- Can we increase the hosting capacity of LV networks?
- Mitigation Actions explored:
  - Loop operation of LV networks.
  - OLTC operation in 11kV/430V Transformers.
  - Energy Storage
Mitigating Action: Loop Connection

- **Objective:**
  - Explore and identify the technical benefits of meshed operation in LV feeders (typically operated in radial configuration).

- **Methodology:**
  - One real LV network is modelled without (radial operation) and with meshed connection (the connection was also explored in pairs).

<table>
<thead>
<tr>
<th>Way_NO</th>
<th>Number of Segments</th>
<th>Length [m]</th>
<th>Number of MPANs</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1141</td>
<td>2290</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>483</td>
<td>868</td>
<td>31</td>
</tr>
<tr>
<td>2</td>
<td>499</td>
<td>920</td>
<td>26</td>
</tr>
<tr>
<td>1</td>
<td>865</td>
<td>1287</td>
<td>53</td>
</tr>
<tr>
<td>Total</td>
<td>2988</td>
<td>5365</td>
<td>180</td>
</tr>
</tbody>
</table>
Utilization Level: Two-Feeders linked/Case I

Before

Connection between feeder 1 and 4

After

Feeder 4

Feeder 1
Voltage Problems: Two-Feeders linked/Case I

Before

After

Feeder 4

Feeder 1

Connection between feeder 1 and 4
Utilization Level: Two-Feeders linked/Case II

Before

After

PV Penetration [%]

PV Penetration [%]

Subte1 - Feeder4

Subte1 - Feeder3

Connection between feeder 3 and 4
Voltage Problems: Two-Feeders linked/Case II

Connection between feeder 3 and 4

Before

After

Feeder 4

Feeder 3
Mitigating Action: OLTC Operation

- **Methodology:**
  - Impact Assessment Methodology

- **Technologies:**
  - Photovoltaic panels (PV)
  - Electric vehicles (EV)

- **Cases under analysis:**
  - Business as usual (without OLTC)
  - OLTC with local control
  - OLTC with remote control

- **OLTC features:**
  - Control cycle 5 minutes.
  - Regulation +/-8%.
  - 9 tap positions.

<table>
<thead>
<tr>
<th>Feeder</th>
<th>Length (m)</th>
<th>No. of Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2479</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>1823</td>
<td>68</td>
</tr>
<tr>
<td>3</td>
<td>2312</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>779</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>670</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>1220</td>
<td>49</td>
</tr>
</tbody>
</table>

Network used:
OLTC Operation: Results

**Without Control**

**Local control:** Information from the busbar Voltage target: PV 235V, EV 245V

The voltage problems are solve for the EV case.
OLTC Operation: Results

**Business as usual**

The voltage problems are solved for the EV case.

**Remote control:** Information from the furthest customer in the longest feeder.
OLTC Operation: Results

Business as usual

Remote control: Information from the furthest customer in the longest feeder

Modification in the OLTC Design: +12%/-4%
Mitigating action: Energy Storage

- Explore the utilization of energy storage units in specific locations in the feeder to increase the PV hosting capacity.
- Cases to explore:
  - One house/one battery
  - One feeder/one battery

Feeder 4: 2.2 km 70 loads
Energy Storage: One House/One Battery

The battery is sized to use most of the energy stored during the day.
Energy Storage: One Feeder/One Battery

- Part A + Part B = Total feeder
- Part B has X% of the customers downstream.

The battery is in follow mode according to the net demand. The size is selected to used the energy daily.
One Feeder/One Battery: Voltage Analysis

![Graphs showing PV penetration vs customers for different storage scenarios.](image)

- **No Storage**
- **Storage at bus with 50% of customer downstream**
- **Storage at bus with 75% of customer downstream**
Energy Storage: Comparison

- One house/One Battery and One Feeder/One Battery

The problems are delayed from 40% (base case) to 80% and the magnitude of the problems is similar in both solutions.
Energy Storage: How to decide?

- One house/One Battery (using the energy stored)
- One Feeder/One Battery (75% of the feeder)

Capacity and Energy

- Battery Size [kW]
- Battery Energy [kWh]
- PV Penetration [%]
Energy Storage: How to decide?

One house/One Battery (using the energy stored)

One Feeder/One Battery (75% of the feeder)

Capacity Cost: 400 US/kW
Energy Cost: 300 US/kWh
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  - OLTC
  - Energy Storage
- Economic Assessment
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Economic Assessment

- Benchmarking Cost: How much is the network reinforcement cost for enabling certain LCT penetration?

- Network reinforcement:
  - Traditional approach to face load growing.
  - Very expensive alternative (mainly due to the installation cost).
  - 140 £/m for main cables and 80 £/m for services cables (urban areas).
Economic Assessment: Network Reinforcement

The following algorithm has been implemented:

1. Identification of customers with voltage problems.
2. Identification of the “worst customer” (voltage rise or voltage drop)
3. Identification of the main path between the secondary substation and the worst customer.
4. Division of the main path in segments of 100 meters.
Economic Assessment: Network Reinforcement

5. For the first segment (100 m) the cable is replaced by the next bigger cable available.

6. A power flow is run and the voltages are checked:
   5. If the voltages are not yet within the Standard:
      5. and there is still one bigger cable available, go to step 5.
      6. If there is not a bigger cable available, go to step 5, but for the next 100 m segment.
   6. If there are not more problems, stop.
Economic Assessment: Network Reinforcement

7. Once the voltage problems are fixed, the thermal problems are checked.

7.1 Each cable with thermal problems is replaced for the minimum size bigger than the rating required.
Economic Assessment: Loop Connection

- Network reinforcement cost:

![Graph showing PV penetration vs. cost]
### Loop Connection cost:

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Voltage Level</th>
<th>Assumptions</th>
<th>Unit Costs</th>
<th>Installation Costs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link Box</td>
<td>LV</td>
<td>Replacement or new link boxes to create mesh points from Network Studies</td>
<td>£ 650</td>
<td>£ 1,298</td>
<td>£ 1,948</td>
</tr>
<tr>
<td>Link box Switch</td>
<td>LV</td>
<td>3 for every link box or mesh point (assume 1 link box for every 2 LV feeders)</td>
<td>£ 2,000</td>
<td>£ 135</td>
<td>£ 2,135</td>
</tr>
<tr>
<td>Gateway</td>
<td></td>
<td>1 per every 3 link box switches plus 1 per distribution substation</td>
<td>£ 1,250</td>
<td>£ 135</td>
<td>£ 1,385</td>
</tr>
<tr>
<td>Circuits breakers (Weezap)</td>
<td>LV</td>
<td>3 for every LV feeder</td>
<td>£ 4,500</td>
<td>£ 135</td>
<td>£ 4,635</td>
</tr>
<tr>
<td>Joints</td>
<td>LV</td>
<td>2 Joints required for each new link box</td>
<td>£ 100</td>
<td></td>
<td>£ 100</td>
</tr>
<tr>
<td>Cable</td>
<td>LV</td>
<td>Assume 10m per new link box + extra for interconnection points from Mark's work</td>
<td>£ 17</td>
<td></td>
<td>£ 17</td>
</tr>
<tr>
<td>Monitoring</td>
<td>LV</td>
<td>1 every five LV feeders. Measuring the most electrically remote point from each distribution substation</td>
<td>£ 2,205</td>
<td>£ 2,100</td>
<td>£ 4,305</td>
</tr>
</tbody>
</table>

Two Feeder Connection without monitoring: £13,931

is this expensive?
The loop connection is not solving the problems for the penetration levels when it is cheaper than the reinforcement cost.
Economic Assessment: Loop Connection

How can we decrease the cost? Replacing the CB by fuses – new cost £4,661

Now the network reinforcement for this network is competitive – Challenge: How is the reliability affected?
Economic Assessment: OLTC

- Network reinforcement cost:
Economic Assessment: Loop Connection

OLTC: £36,000  
OLTC+ICT: £40,000

The OLTC is more economic efficient for higher penetration levels.
Outline

- Objectives
- Problem Description
- Profiles Creation
- Impact Assessment
- Multi-Feeder Analysis
- Mitigating Actions
- Conclusions
Conclusions

- Loop connection of LV feeders
  - Is effective as it “shares” the problems
  - PV hosting capacity was significantly increased (From 40% to 70%)

- OLTC in LV networks:
  - It increases the hosting capacity and reduces the magnitude of possible problems
  - The monitoring can be incorporated progressively with the LCT penetration.
Conclusions

- **Energy Storage:**
  - The storage sizing must take into account the capacity of using the energy stored (otherwise the problems could be shifted from one day to another).
  - The “one house/one battery” approach leads to a higher installed capacity than the “one feeder/one battery” approach for similar results.

- **Network reinforcements**
  - Still play an important role but depends on the forecast LCT penetration
Dissemination: Publication List


Collaborations related with LCTs:


Dissemination: Work in Progress

Publications Submitted:


Work in progress:

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