Managing the renewables challenge in secondary distribution networks

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Managing the renewables challenge in secondary distribution networks

1. Challenges in grid management
2. Monitoring LV Networks
3. Load Profiles
4. Voltage Optimisation
5. Fault Detection
6. Looking ahead
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Challenges in grid management

Passive Electrical Networks

- Centralised Power Generation
- Grid supply points
- Distribution Networks
  - Normal operation
  - Fault conditions
  - Abnormal operations
  - One-directional power flow
- Predictability
  - Voltage profiles
  - Load factors
  - Fault currents levels

Power Flow
Challenges in grid management

Active Electrical Networks

- Growth in:
  - Large scale Renewable Energy Sources (RES)
  - Distributed Energy Sources (DES)
  - Low Carbon Technologies (LCT)

- Distributed Energy Sources
  - Bi-directional Power Flow
  - Higher voltage profiles
  - Intermittent nature
  - Less predictable
Challenges in grid management

Addressing generation short fall

• Access to electricity
  • Generation shortfall
  • Reliable access
  • Disruption-linked outages
  • Network Intelligence

• Challenges in grid management
  • “Last mile” of the distribution network
  • Planned & predicted in the past
  • Variable now & in future
  • Customer take-up
Challenges in grid management

Load Profiles

- Traditional models predictable, based on:
  - Metering points
  - MDI readings
  - HV load data

- Challenges to this model:
  - Embedded generation
  - Weather
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Monitoring LV Networks

System Architecture

- Control Room
  - SCADA / DMS
- MV Primary
  - RMU
  - MV/LV Transformer
- MV Overhead Lines
  - Switches
  - Pole mounted MV/LV Transformer
- LV Feeder Pillars
- LV Monitoring
- LV Cut-outs
- LV Monitoring

Data Analytics
Monitoring LV Networks

Gridkey Substation Equipment

- Safe retrofit
- IP65
- 5 feeders (20 conductors)
- Class 1 accuracy
- over range 4-720A
- Alarms & reports
- Communications

MCU (Metrology and Comms Unit)
Current sensors
Voltage taps via G-Clamps on the bus-bars
Monitoring LV Networks

Gridkey Substation Equipment

- **Sampling**
  - 8kHz
- **Monitoring**
  - 5 Hz (ten line cycles, IEC 61000-4-30)
- **Statistical Data**
  - Reporting period adjustable
  - Can be altered remotely
  - Analysis at data centre
- **Instantaneous data reporting**
  - Average, max and min reports
  - Programmable alarms
- **Highly efficient data comms protocol**

Lucy Electric
GridKey MCU520
Current Sensors

- GridHound Rogowski sensor designed specifically for LV monitoring
  - Sized for 300 mm2 Wavecon
  - 0.5 class accuracy
- Flexible Rogowski sensors
- Types can be mixed
# Monitoring LV Networks

## NoSQL database

- >60 billion data points stored in data centre
- Hierarchical dashboards, web portal,

<table>
<thead>
<tr>
<th>Average kVA</th>
<th>Load factor</th>
<th>Max kVA</th>
<th>Average V</th>
<th>Over V</th>
<th>Under V</th>
<th>Feeder Av</th>
<th>Feeder Max</th>
<th>Feeder Peak</th>
<th>Max neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>23%</td>
<td>65%</td>
<td>35%</td>
<td>108%</td>
<td>86%</td>
<td>0%</td>
<td>46%</td>
<td>81%</td>
<td>237%</td>
<td>39%</td>
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<tr>
<td>23%</td>
<td>58%</td>
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<td>71%</td>
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<td>0%</td>
<td>14%</td>
<td>62%</td>
<td>67%</td>
<td>39%</td>
</tr>
</tbody>
</table>

| Average current | 302 | 42% | 146.8 | 37% | -22.0 | -6% | 182.9 | 46% | -23.3 | -6% | 21.3 | 5% |
| Max 1 minute current | 488 | 67% | 268.8 | 67% | 16.4 | 4% | 324.3 | 81% | 15.4 | 4% | 87.6 | 22% |
| Peak current | 499 | 69% | 272.0 | 68% | 18.6 | 5% | 947.6 | 237% | 23.3 | 6% | 203.4 | 51% |
| Min 1 minute current | 134 | 19% | 51.5 | 13% | -59.63 | -15% | 83.625 | 21% | -62.13 | -16% | 10.5 | 3% |
| Average neutral | 80 | 11.0% | 19.4 | 5% | 6.9 | 2% | 29.9 | 7% | 7.4 | 2% | 16.0 | 4% |
| Max 1 minute neutral | 165 | 22.7% | 48.125 | 12% | 19.375 | 5% | 118.13 | 30% | 20.375 | 5% | 63.875 | 16% |
| Peak neutral | 723 | 99.7% | 76.0 | 19% | 21.9 | 5% | 673.9 | 168% | 23.0 | 6% | 208.8 | 52% |
| Average current imbalance | 80 | 26.4% | 13% | -31% | 16% | -32% | 75% |
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4. Voltage Optimisation
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Residential PV on a sunny day in England …
Load Profiles

Busbar Mean Current Values up to 02/05/2013

The graph illustrates the mean current values for busbar over time from 02/05/2013.
Load Profiles

Busbar Mean Voltage Values

Busbar Mean Voltage Values up to 02/05/2013

Volts

02May 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00

Time
Load Profiles

Busbar Mean Active Power

Busbar Mean Active Power Values up to 02/05/2013
Load Profiles

Busbar Mean Reactive Power

Busbar Mean Reactive Power Values up to 02/05/2013
Residential PV on a sunny day in England …

- Net export to grid (during 08:00 – 16:00)
  - Current reversal
  - Small amount of reactive power
  - Voltage within limits
Load Profiles

Residential PV on a typical sunny day in England …
Load Profiles

Busbar Mean Current Values

Busbar Mean Current Values up to 13/05/2013

Amps

13May 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00

Time

www.eapicforum.com
Load Profiles

Busbar Mean Voltage Values

Busbar Mean Voltage Values up to 13/05/2013

Volts

13May 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00

Time

www.eapicforum.com
Load Profiles

Busbar Mean Active Power Values

Busbar Mean Active Power Values up to 13/05/2013
Load Profiles

Busbar Mean Reactive Power Values

Busbar Mean Reactive Power Values up to 13/05/2013
Load Profiles

Residential PV on a typical sunny day in England …

• Variable load profile (during 08:00-16:00)
  – Forward & reverse currents
  – Voltage within limits
  – Small amount of reactive power
Load Profiles

PV installation, on an overcast day in England …
Load Profiles

Busbar Mean Current Values

Busbar Mean Current Values up to 11/04/2013

Amps

11Apr 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00

Time
Load Profiles

Busbar Mean Voltage Values

Busbar Mean Voltage Values up to 11/04/2013

Volts

Time

11Apr 02:00 04:00 06:00 08:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00

230 232 234 236 238 240 242
Load Profiles

Busbar Mean Active Power Values

Busbar Mean Active Power Values up to 11/04/2013

Watts

Time

www.eapicforum.com
Load Profiles

Busbar Mean Reactive Power Values up to 11/04/2013
Load Profiles

PV installation, on an overcast day in England ...

- **Forward current profile**
  - Active power rises during day
  - Minimal reactive power forward & reverse
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5. Fault Detection
6. Looking ahead
• Tracking voltage performance

• Fraction of time in voltage bands
  • > 253 V (+10%)
  • 247-253 V (+ 7.5% to +10%)
  • 221-247 V (-3.5% to +7.5%)
  • 216 – 221 V (-6% to -3.5%)
  • < 216 V (-6%)
Each row is a substation

Measured voltage
Voltage Optimisation

• **Network Challenges**
  - Traditional curve voltage drop
  - Reverse Power Flow
  - Voltage Rise with PV
  - Equipment Ratings

• **Solutions**
  - Improve network utilisation
  - Limit / control the connection of PV
  - Introduce automatic voltage regulation on LV networks
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Fault Detection

Intermittent pre-fault current spikes

- LV cable failures
  - Mechanical damage
  - Jointing faults

- What to look for
  - Instantaneous peak currents in excess of normal loads
  - Clustered events

- Health index for cables
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Looking Ahead

Actionable Information

- **Planning**
  - Asset Management
  - Reinforcement

- **Power Quality**
  - Voltage profiles
  - Total Harmonic Distortion

- **Losses**
  - Technical Loss
  - Non-technical Loss

- **Faults**
  - Predict
  - Detect
  - Analyse
  - Fix

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Looking Ahead

Integration into Monitoring and Control Systems

Control Room
SCADA / DMS

MV Primary
RMU

MV/LV Transformer

LV Feeder Pillars
LV Monitoring

RTU

Data Analytics

Alarms
Min
Max
Set-points
Integration into Monitoring and Control Systems

- **Geospatial network views**
  - Real-time outages
  - Load profiles / modelling
  - Blown fuses / broken conductors
  - Under / over voltage
  - Location of LV faults

- **Managing “Electrical Headroom”**
  - Network reconfiguration
  - Embedded generation
  - Energy storage
  - Demand response

Lucy Electric SCADA system, courtesy of SKELEC
Looking Ahead

Integration into Monitoring and Control Systems

- Response to generation shortfall
  - More management tools
  - Quality of service
  - Intermittent generation
  - Bi-directional power flows

- Visibility and Active Management
  - Centralised control points
  - Microgrids
  - Off-grid

- Data has more than one use
  - e.g. may assist asset management
THANK YOU

Q & A