Using smart meter data to improve quality of voltage delivery in public electricity distribution networks
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HEALTH, ENGINEERING AND SCIENCE

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Jemena Electricity Networks

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Agenda

• Background of the research project
• What has been revealed so far
• Conclusions
• Future research direction
LV Voltage Delivery – Current Situation

- Australian electricity distribution companies are regulated by the National Electricity Rules and state based regulations for the quality of electricity they deliver to the customer supply points – such as voltage magnitude.
- Voltage non-compliance has high societal cost as it affects efficiency and life expectancy of electrical equipment.
- Voltage magnitude is measured at strategic locations on the network but not at individual customer premise.
- Electricity distribution companies normally react to customer complaints of over and under voltages and take corrective actions.
Smart Meter Rollout in Victoria, Australia

- Victorian state government in Australia mandated the rollout of smart meters
- The Advanced Metering Infrastructure (AMI) Program started in 2009 and scheduled for completion in 2013
- Mandated program covers all customers consuming under 160MWhr per annum
- Smart meters linked by two-way communication network to a central back office system
- 30-minute energy consumption as well as power quality events such as over and under voltage
- Voltage monitoring now down to individual customer point of supply
Snapshots of Under & Over Voltage Events

- The data analysis was carried out on approximately 100,000 smart meters installed on Jemena Electricity Networks (JEN, with about 315,000 customers)
- Graph shows over and under voltage events recorded by smart meters over six consecutive days in Feb 2012, with X-axis being the maximum temperature on each day
- Overvoltage an on-going issue but undervoltage also arises at high ambient temperature days
- 260MByte of event data for 1-month of overvoltage and 3-month of undervoltage events
- The volume of event data requires efficient data manipulation and analysis
Under & Over Voltage Events – Start Times

- Majority of undervoltage start times between noon to 8pm, coinciding with peak electricity usage on high temperature days
- Highest number of overvoltage starts between 8pm to 2am, coinciding with low electricity usage
- There are also significant overvoltage starts at other times. Could this be due to photovoltaic generation?
Under & Over Voltage Events – Event Duration

- Longest undervoltage event lasted nearly 15 hours
- Majority of undervoltage events lasted between half an hour to eight hours
- Longest voltage event lasted nearly 45 hours
- Majority of overvoltage events lasted between 2 to 15 hours.
Under & Over Voltage Events – Extreme Voltages

- Smart meter event records include lowest (or highest) voltage during the event duration
- Majority of minimum voltages are just below the regulatory threshold of 230V-6% (216V)
- Majority of highest voltage excursion are just above the regulatory threshold of 230V+10% (253V)
- Adjustment of distribution transformer tap positions or zone substation voltage regulation set points could be an effective solution
Common Under and Over Voltage Sites

• 12,251 sites experienced overvoltage over the 6-day period
• 6,131 sites experienced undervoltage over the same 6-day period
• 88 sites have experienced both over and under voltage
• These sites cannot be rectified by adjusting the upstream supply voltages
• Analysis indicates that some sites are supplied from overloaded distribution substations requiring network reinforcement
• Further investigation is underway
Impact of Rooftop Solar Installations

- Analysis of overvoltage event start times indicates there are higher portion of PV sites giving rise to overvoltage events between 8am to 2pm.
- This could suggest PV generation is contributing to overvoltage issues, although still moderate at this stage.
- Graph shows a PV household 30-minute usage profile. Channel 2 captures net energy exported back into the grid.
- Even on a reasonably sunny winter day PV reduced household consumption and exported net energy back into the grid.

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Total number of OV events generated by PV sites</th>
<th>Total number of OV events</th>
<th>% of PV sites OV events to total number of OV events</th>
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<tbody>
<tr>
<td>00:00-02:00</td>
<td>228</td>
<td>5718</td>
<td>4.0%</td>
</tr>
<tr>
<td>02:00-04:00</td>
<td>63</td>
<td>2246</td>
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<td>04:00-06:00</td>
<td>57</td>
<td>2223</td>
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<td>06:00-08:00</td>
<td>116</td>
<td>3399</td>
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<td>08:00-10:00</td>
<td>122</td>
<td>2415</td>
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<td>10:00-12:00</td>
<td>92</td>
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<tr>
<td>22:00-00:00</td>
<td>283</td>
<td>8092</td>
<td>3.5%</td>
</tr>
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</table>

Red bars indicate net export.
Linking Sites to Upstream Supply Substations

- Network connectivity – from zone substation through to distribution substation and to individual customer – is provided in Geographical Information System (GIS)
- Linking smart meter voltage quality data with GIS data allows clusters of under and overvoltage sites (supplied from same sources) to be identified
- Review of voltage regulation and off load tap settings can then proceed

Diagram:

- Zone Substation
  - Distribution Substation 1
    - With off-load taps
      - OV site 1
      - OV site 2
      - OV site 3
  - Distribution Substation 2
  - Distribution Substation n

With automatic voltage regulation and on-load transformer tap changing
Conclusions

• Mass rollout of smart meters with voltage quality monitoring capability has allowed electricity supply authorities to adopt a proactive approach for voltage quality compliance
• The large volume of smart meter voltage quality data requires efficient data analysis techniques to extract relevant actionable information
• Research work presented in this paper has allowed an overall picture to be developed
  – Relationship of under and over voltage events to ambient temperatures
  – Severity of voltage events in the form of durations and extreme voltages
  – Start times of under and over voltage events
  – Relationship between over voltage events and domestic photovoltaic installations
  – Linking voltage events to upstream supply substations
• These observations will assist supply authorities to prioritise its voltage quality rectification program
Future Research Direction

• Future research effort will focus on identifying the possible causes and rectification of the voltage quality issue
  – Linking voltage quality problem to incorrect transformer tap setting of upstream distribution substations
  – Linking voltage quality problem to incorrect voltage regulation settings of upstream zone substations
  – Linking voltage quality problem to overloaded distribution circuits and substations
  – Linking voltage quality problem to phase unbalance
• Identifying the impact of domestic photovoltaic installations on voltage quality
  – Modelling the maximum PV penetration without violating voltage quality regulation
• Develop innovative voltage control strategy that will maximise the penetration of embedded generation on the distribution networks
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