LV STATCOMs and Storage for Voltage Management in Distribution Systems

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Overview

• Overview of Low Voltage network management problems
• Overview of potential solutions
• LV STATCOMs
• Desired features of STATCOMs
• The Power IQ / Toshiba Volt Pro
• Energy storage
• Challenges with control of storage
• The Power IQ / Toshiba SRS
• Observations from Japan
Overview of LV management issues
aka A Brief History of LV Networks

• LV networks traditionally “invisible” to utilities:
  – Planning studies stopped at MV
  – LV design standards based on uni-directional power flow and voltage drop
  – LV records generally poor
  – No real time voltage measurement
  – No major problems despite short arm linesmen
  – Customers generally happy
  – Life was good (no worries)
Then along came PV

- PV output highest in the middle of the day when load is lowest
- Net Feed-in tariffs encouraged consumers to shift load away from middle of the day.
- Bi-directional power flow meant much greater voltage swing both steady state & dynamic
- Feed-in tariffs encouraged customers to complain when voltage went out of spec.
- Unbalance can be exacerbated
- Big(gest) pain for utilities in an area where they have lowest visibility.

![Tracking Change – 46kV Level](chart.png)
Most of the voltage swing occurs down the LV network itself

Need a solution on the LV Network
### Potential solutions

<table>
<thead>
<tr>
<th>Solution</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce tap setting</td>
<td>Simple, low cost</td>
<td>Doesn’t solve voltage swing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Requires customer outage</td>
</tr>
<tr>
<td>Augmentation (split LV, bigger conductor etc)</td>
<td>Well understood</td>
<td>Expensive, requires outage, not addressing core issue.</td>
</tr>
<tr>
<td>Series LV compensators</td>
<td>Directly addresses voltage problems</td>
<td>Not that widely applicable, fault tolerance?</td>
</tr>
<tr>
<td>Change in voltage regulation</td>
<td>Potentially low cost</td>
<td>Not addressing issue</td>
</tr>
<tr>
<td>LV STATCOM</td>
<td>Low cost, easy retrofit, multiple benefits</td>
<td>Not effective on high R/X or short networks</td>
</tr>
<tr>
<td>LV STATCOM + storage</td>
<td>Solves voltage &amp; peak load issues. Works on high R/X networks, many multiple benefits</td>
<td>Expensive</td>
</tr>
<tr>
<td>Customer owned “VAR capable” inverters</td>
<td>Low cost - Customer pays for the solution</td>
<td>Long term. Need standardised VAR control algorithms.</td>
</tr>
</tbody>
</table>
LV STATCOM Operation

STATCOM injects (capacitive) VARs during peak load periods and absorbs (inductive) VARs during light load periods to stabilise network voltage.
- Power quality improvements, meeting statutory requirements
- Allows higher PV penetration
- Solution on DNSP side in DNSP control
- Provides a economical way of managing issues caused by high penetration of PV
Desired features of LV STATCOMs

Hardware related

• Pole mounted IP65
• High reliability / low maintenance
  – Natural convection, 15 year design life
• 10kVA single phase / 30kVA 3 phase
• 50 degC ambient with > 1000 W/m² s loading
• Wide voltage range eg. 210-270V
• Low harmonics
• Low audible noise
• AS4777 compliance
Desired features of LV STATCOMs
Software Related

- **Droop control**
  - To ensure stable operation with multiple units from different vendors
- **Data logging & communications**
  - To provide utilities with visibility of LV network
- **AFLC support**
  - Present high impedance at AFLC frequencies
  - Potentially generate AFLC signals?
- **Low harmonic output**
- **Active harmonic filtering**
Power IQ/Toshiba offer

- Volt Pro will be sold through Toshiba, with Toshiba’s warranties, service and support.
- Local design for Australian conditions & local expert support/customisation
- Dual branded Toshiba & Power IQ.
Addition of storage

• LV STATCOMs assist utilities to accept increased levels of PV penetration (~30%)

• Ultimately for higher levels of penetration (>30%), storage can be added.

• Utility owned storage requirements:
  – High temperature
  – Long life
  – Reliable
  – Control to suit network needs? (eg. Q based on V, P based on Loading).
Challenges with control of storage systems

• Control requirements of DNSPs, Retailers and Customers often conflict with each other.
• Even without the above conflicts, the distributed nature of the problem makes control problem complex (need to control both local and aggregated peaks).
• Lack of standardisation of control methods are a worry.
Different Control Objectives

• Customer:
  – Reduce electricity bill / make money
  – Back-up power during outages
  – Improved power quality in rural & remote regions
  – Will respond to tariffs (eg. TOU)

• Retailer:
  – Reduce exposure to wholesale electricity price fluctuations

• Distribution Network Service Providers
  – Reduce network peaks (local & aggregated)
  – Improve voltage

• THESE ARE OFTEN CONFLICTING REQUIREMENTS
• NEED TO DEVELOP POLICIES AND CONTROL METHODOLOGIES TO BENEFIT ALL ELSE “HE WHO HAS THE GOLD MAKES THE RULES”.
Control challenges:
Ergon experience with scheduled control

- Tariffs such as TOU rely on timed scheduling.
- A recent study showed that scheduled peak load reduction was unsuccessful 72% of the time at the Distribution Transformer level, due to load variability and low diversity.
- Central control and timed tariffs/scheduling cause loads to change simultaneously and therefore reduce load diversity.
- This can create secondary peaks and have the opposite result to the control objective.
BESS Industry Survey

- Market survey – around 60 market entrants in Australia or planning to be in Australia (based on Mar-May 2014) – includes packaged batteries (Akasol, Tesla, SAFT), multiple-mode inverters (Nedap, Selectronics, SMA), packaged systems (BYD, Panasonic, Sunverge, ZEN), kit systems (mygrid and All-Grid) and system integrators (Reposit and Geli)
- Different backgrounds in development – IT, SPS, entrepreneur, battery manufacturers
- Control methodologies are varied – no consistency
- Limited understanding of how the systems work and limited documentation on how they are controlled
- Prices are hugely variable
- Level of local support and understanding is variable
- Limited understanding of true value proposition for utilities - DNSP
The systems do:

- Shift energy
- Store solar energy
- Work on a time clock
- Can meet energy needs
- No specific load management or even load response control
- No grid interface management

Generally:

- Operation of charging and discharging based on a time clock
- Monitors battery state of charge and battery energy
- Offers some form of back-up power
- Solar – it depends – DC coupled or AC coupled

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Control conclusions

• Conflicting requirements of retailers, DNSPs & the customer.
• At a local level the lack of diversity makes simple time scheduled methodologies problematic.
• No standardisation amongst manufacturers. Most current systems based on time scheduling
• Heading for trouble.
• Solutions?
  – Principal: Solutions should lead to lowest societal cost.
  – Max Demand Control / Capacity tariffs.
  – Voltage support.
Demand limiting

- A maximum demand / capacity tariff should be implemented for residential.
- Measurement at higher sample rate than ½ hour.
- Battery systems could be used to minimise the maximum demand.
Voltage support

• Many PV inverters and battery inverters have the capability to inject and absorb reactive power, so could be used to support LV network voltage.

• What is lacking is an incentive.

• First step could be to charge customers for kVArh not kWh – encourage them to maximise their total power factor. Inverters could be used to correct their power factor thus lower their bill.

• Ultimately best to incentivise customers to support network voltage.
Power IQ/Toshiba Smart Residential Supply (SRS)

- Advanced control
  - Programmable Maximum Demand Limit
  - Programmable Export limit: Limit feed-in to grid
  - TOU: Minimise consumption during peak periods
  - Customer load control.
  - Voltage support, power factor compensation

- Premium battery quality & integrated BMS
  - Toshiba SCiB Lithium Titanate batteries
  - 15+ year design life/>10 000 cycles @ 100% DOD
  - Excellent temperature range / performance
  - Excellent safety by design

- Next generation power electronics
  - World leading ultra low loss (<1.5%)
  - No fans => Low maintenance & high reliability, 15 year design life
  - Very compact
  - Low harmonic output (0.8% THD)

- Flexible
  - Custom Apps
  - Expandable storage
  - Modular design allowing future add-on modules.

<table>
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<tr>
<th>Specification</th>
<th>Rating</th>
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<tbody>
<tr>
<td>Battery Converter</td>
<td>10kVA</td>
</tr>
<tr>
<td>Power rating</td>
<td></td>
</tr>
<tr>
<td>Storage (usable)</td>
<td>8.8kWh</td>
</tr>
<tr>
<td>Max. Operating Temperature</td>
<td>45°C</td>
</tr>
<tr>
<td>AC connected PV</td>
<td>supported</td>
</tr>
<tr>
<td>Customer load control</td>
<td>supported</td>
</tr>
</tbody>
</table>
Power Converter System (PCS) (the core technology)

Natural Convection (Fan-less design)
SRS Prototype

Power IQ
VoltPro
STATCOM
10kVA SRS compared to leading 5kVA PV inverter – a new benchmark

Power IQ SRS is \( \frac{1}{2} \) the size of a leading 5kVA PV inverter.  
⇒ \( \frac{1}{4} \) of the size on an equal power basis.

And it is naturally cooled => no fans or moving parts.
Observations from Japan

• Japan ~ 5 x population of Australia but electronics & manufacturing industries many times larger.
• Highly nationalistic, utility contracts exclusively awarded to Japanese companies.
• Trials are generally bigger and more well funded, enabling more vendor interest.
• Central Government support of renewables & storage.
• Storage deployment is considerably advanced compared to Australia (probably due to Fukushima).
• Quality focus
Observations from Japan
Storage / anti-islanding

• Initially active anti-islanding methodology was up to vendors (similar to AS4777).
• With higher deployment of storage, utilities realised they could not guarantee anti-islanding with multiple battery converters from different manufacturers anti-islanding algorithms.
• Manufacturers therefore have come together and agreed on a specific anti-islanding algorithm (JEM-1498).
• Also, agreement on a common Fault-Ride-Through algorithm.
• This ensures networks with converters from multiple manufacturers will trip/operate correctly.
• This is possibly something Australia should look at.
Conclusions

- LV STATCOMs are cost effective solutions to assist utilities to integrate high levels of renewables.
- Storage can be added to increase level of integration further.
- Control of storage systems is the key to whether storage is beneficial or not to the network.
- A lot of development needed on control and tariffs.
- Power IQ / Toshiba will be releasing 10kVA STATCOM & Storage products locally & internationally.
- As levels of penetration of storage increases Australia should consider:
  – Battery standards.
  – Control methodologies & tariffs.
  – Defined Common Anti-islanding algorithms.
  – Defined Common Fault Ride Through algorithms.
Thank you for your attention

Questions?