### Distributed PV Integration Concerns

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### Summary of Global Experience

- **Voltage rise & impact on voltage profile, reverse power flow**
  - In general has not been a problem, but can limit installs in some cases (i.e. long rural feeders)
  - Distribution system in Germany more modern than much of US (bidirectional relaying is the norm)
  - System upgrades in the US will definitely facilitate more PV – but needed regardless of PV
- **Visibility and Control**
  - Monitoring and real / reactive power control of large systems (10 MW+) generally provided (SCADA)
  - Lack of visibility, control of smaller DG generation is a significant concern
  - German TSOs use regional level estimates and forecasts of PV generation (4-5% RMSE)
  - German TSOs also will have basic curtailment control via low-cost infrastructure (ripple control)
  - Spain now requires telemetry from larger systems to TSO; also forecasts PV
Neither German or Spanish DSOs have real-time visibility

US approach is a work in progress:
- Perception of a need for data from all PV systems into dist. ops. from some US utilities
- Utility SCADA comms to mid-size systems (100’s of kW) extremely expensive, not scalable
- “Gating” high penetration PV by rollout of SG comms will likely be a barrier
- Discussion in US must mature – what data is needed, what resolution (time / space), when (ops vs. planning)

- Unintentional islanding, Short circuit contribution
  - Unintentional islanding often a significant worry for utilities in US, but not in Europe
    - European studies and experience indicate that risk is extremely low.
    - US perceptions are often not well informed.
  - Short circuit contribution has not been a problem to date but often a discussion point in technical circles.
- “Sympathetic” tripping of DG
  - Need for DG to trip on local fault but ride through transmission fault.
  - Unlikely to be an issue until high penetration (one study showed an issue at ~20% of system energy)
  - Germany preparing for high penetration by requirement of voltage and frequency ride-through for DG.
  - Expect similar Europe-wide requirements from ENTSO-E.
  - NERC (IVGTF) and IEEE 1547.8 committee addressing this by developing standard.

- Fault Behavior of Large Plants
  - Requirements for large PV plants follow from current wind and conventional plant requirements.
  - EU was burned by lack of wind requirements, leading to difficult recovery from 2006 UCTE breakup.
  - No technical barrier to meeting requirements (e.g. voltage / frequency ride through)
  - One issue (particularly in US) is lack of standards or test protocols for non-DG PV inverters / plants.

Conclusions
- Local impacts of PV variability on the distribution system do not appear to be a significant issue in general, and can be managed with advanced controls if needed.
- Penetration of VERs up to ~20-30% of energy has been shown to be manageable, with current technology and generation mix, in multiple recent in-depth studies.
- Accurate forecasts; flexibility (flexible generation, energy storage, demand response); operation strategies; transmission; and changes to markets & policies will
all reduce integration costs now and may be necessary to achieve VER penetrations beyond ~ 30% without excessive curtailment.

- The combination of storage and PV to provide added value to the customer appears promising. Technical and economic validation is in progress.
- Significant amounts of high penetration (>100% of minimum load), distributed PV generation have been successfully integrated worldwide.
- Geographical diversity substantially mitigates short duration variability, even within the footprint of a given feeder.
- Many often discussed concerns such as voltage fluctuation, failure of anti-islanding, and unacceptable harmonic contribution have not emerged in practice.
- Experience in Germany and Spain suggests that mid-term goals (e.g. 33% RPS in CA by 2020), even with PV predominately deployed as DG, is readily achievable with no significant technical barriers.
- Functionality similar to that required by German MV directive, applied to all PV systems, is expected to be adequate to meet much higher penetration levels in Germany moving forward.
- European studies indicate that reactive power control of DGPV significantly increases the ability of a circuit to accommodate PV without requiring other upgrades.
- Distribution system upgrades to current state of the art will substantially increase allowable penetration levels, benefit many stakeholders including utilities and all their customers.

Daniel Ruoss, Solar Systems
Mildura CPV Power Facility

Issues to address in the short-term:

- Capacity and skills building with Network Service Providers (NSP) and Transmission Operators
  - we have to work hard to get solar as a positive message across and that everyone is aware of the many benefits.
  - Solar needs to be considered as enormous opportunity to avoid costly network augmentation and great support for the existing infrastructure.

- Use of reactive power control for maximising high penetration of solar ⇒ lessons learned to be collected
  - To be included in an update for the PV High-Penetration Report by APVA
  - Presentation in conferences and workshops (in Australia)

Issues to address in the medium-term:

- Frequency and low-voltage ride-through (revision of grid codes and standards).
- AS for inverters larger than 30kV (Ted Spooner et al.).
- Forecasting modelling
  - support AEMO in its activities.
For larger-scale solar (to TNSP):

- Fair and firm access to grid infrastructure \(\Rightarrow\) Submission by APVA to AEMC Transmission Framework Review Group.
  - Clear price signals, firm and controlled access to transmission (access regime!)

Issues for Discussion

- Weak grid infrastructure in rural areas
  - Challenge for integration and resulting in costly reinforcement or new distribution and transmission assets, very often pushed to the project developer (or project owner).
- However, the ‘rural areas’ represent often best locations for solar generation. Conclusion; very few spots with good grid infrastructure and great solar irradiance conditions. This will result in a concentration of solar power and cost for land and labour goes up because of the hyped demand (e.g. like the mining boom).
- Upgrade and replacement of aging distribution & transmission structure by Government.
- Fair and reasonable access to grid infrastructure
  - No pioneer scheme (first come first pay).
- Further capacity and skills building with Network Service Providers (NSP) and Transmission Operators
  - We have to work hard to get solar as a positive message across and that everyone is aware of the many benefits.
- Use of reactive power control for maximising high penetration of solar.
- Frequency and low-voltage ride-through (revision of grid codes and standards).
- Forecasting modelling.

Rodger Whitby, Ingenero

*Grid Integration of PV – Issues and Solutions*

Connection Applications can take a long time to process

- Uncertainty around costs until close to the end of the process

Lessons

- ✓ Allow enough time to process and assess the connection
- ✓ Don’t underestimate the costs of connection

Distribution line requires upgrade

- 11kV feeder needs re-conductoring to take full 1MW
- About 1.2km of new HV line
- Full upgrade will take up to 12 months due to Ergon work schedule
- Existing conductor will limit capacity to ~400kW (AC)
- Ergon require assurances that solar farm output can be capped at 400kW or whatever level is determined once they see the actual impact of the solar farm operation
  - The PowerOne inverter can limit active power output in 10% steps
  - This allows for some flexibility as the situation develops
Lessons
✓ Identify network upgrade requirements before you oversize the plant
✓ Don’t underestimate the costs of upgrades

Inverter approval
- In general inverters do not meet the requirements for “automatic connection” under the National Electricity Rules
- In general a quality inverter will usually meet the “minimum” requirements
- A “negotiated connection” is necessary
- There are no Australian standards yet for central inverters
- The distributor has to approve on a case by case basis
- Meaningful feedback on the proposed inverter comes too late in the process
- Ergon’s requirements have been comfortably met by the PowerOne PVI330.0
  - BDEW standards from Germany covered all of Ergon’s concerns

Lessons
✓ Australia needs standards for central inverters to remove uncertainty for developers
✓ Many existing products should be acceptable due to existing foreign standards

- Voltage rise due to feeder conductor size
  - Main control method is reactive power output
  - Ergon required compliance with NER S5.2.5.1 – Reactive Power Capability
    - kVar output at least 0.395 of rated active power level (0.395 x 330kW) at any level of active power output
    - Translates to a power factor of 0.93 at full output
    - Progressively lower power factor at lower output levels
    - PVI330.0 complies
  - Negotiated arrangement with Ergon
    - Fixed power factor of 0.90 lagging
    - Will help hold down voltage on the feeder
  - At what level of Reactive Power does it become an ancillary service?

- Control of active and reactive power from the inverter
  - Visibility and control by Ergon was discussed
  - Not required
  - 400kW just below the brink of control requirement
  - Remote control over set-points is possible with the PVI330.0
    - RS485 or digital/analogue inputs
    - Concern over response time
  - Do we need a standard approach to give developers and manufacturer’s certainty?

Grid Issues at Alice Springs Airport
- Quite variable voltage due to Airport activity patterns
- Usually high voltage on the Airport 11kV ring main
- Caused over voltage on Solar Power Station LV side
- Frequent tripping of SMA11000TL string inverters (active anti-islanding)
- Also inverter underperformance due to impact of high voltage on MMPT range
- Required reset of transformer tap settings
- Common issue for solar on long connections
Commercial & Industrial Systems
- Utility projects seek the best grid connect locations
- C&I projects are usually located at the customer’s property, not necessarily at the best grid location
  - Can be complicated by grid constraints
  - Increased costs
  - Reduced size
- How do we future proof the grid so more power users can generate solar power?

Dr. Iain MacGill, CEEM, UNSW
*High PV Penetration in Electricity Grids, Australian Case Studies for IEA PVPS Task 14*

**Aims**
- Promote the use of grid connected PV as an important source in electric power systems also on a high penetration level where additional efforts may be necessary to integrate the dispersed generators in an optimum manner.
- Develop and verify mainly technical requirements for PV and electric power systems to allow for high penetrations of PV systems interconnected with the grid
- Discuss the active role of PV systems related to energy management and system control of electricity grids
- Reduce the technical barriers to achieve high penetration levels of distributed renewable energy systems on the electric power system.

**Definition of High Penetration by Task 14**
High penetration situation exists if additional efforts are (would be) necessary to integrate the (planned) PV generation in an optimum manner.

**Australia – potential lessons + contributions**
Many common challenges
- Australia a low overall PV penetration by comparison with some other countries
- Lessons from those countries with high PV penetrations and (at least somewhat) similar lines

Some particular Australian challenges relevant to particular task members in some contexts
- Virtually all installed PV is small single-phase systems connected to LV network
- Long weak rural feeders
- Diesel mini-grids

**Some Potential Australian High PV Case Studies**
Alice Springs Solar City
Regional (50MW) grid with gas-fired generation and 3MW of PV,

Case study now completed in partnership with NT Power & Water

High PV diesel mini-grids

Carnarvon Case Study now underway in partnership with Horizon Power

Townsville Solar City

PV with major demand management initiative

Urban contexts

Some preliminary analysis for Solar Cities Blacktown

Other emerging opportunities

Wider objectives for case studies

Engaging key stakeholders for appropriately facilitating high PV penetrations

An emphasis on successful innovation for PV

Case studies of

- Key issues arising from high PV penetrations in a range of Australian contexts
- Successful management of these high PV penetrations
- Identification of future issues and options that support more proactive management in emerging high PV penetrations

Conclusion

growing appreciation that issues increasingly economic, commercial and regulatory, rather than technical

- Emerging PV challenges are more a symptom than cause; most electricity industries have inappropriate arrangements for disruptive technologies

NEM spot market has prices: our retail and network tariffs/fees aren’t prices

- Requires locational and temporally varying and uncertain spot and future prices for both energy and network services
- Major reform of interface between supply and demand sides of electricity industry and NSPs required before genuine ‘price discovery’ can occur, if possible at all
- Little apparent interest or willingness to do this to date by key players

Electricity industries wrt small energy consumers

- Traditionally ‘charge’ schedule of fees’ sufficient to deliver essential current & future access to ‘reliable’ electricity supply ‘service’ s.t. underlying customer ‘class’ costs, wider considerations (eg. equity).
- In restructured industries, an unresolved question, often only limited changes

What arrangements will we ‘choose’ for disruptive technologies like PV, or (past) air-conditioning, or (future) Electric Vehicles?
PV and Australian Utilities

- Boom bust nature of the industry is making it difficult for utilities to get resources to deal with the numbers of PV applications let alone the issues
- Utility has a responsibility to manage the network and everything connected to it effectively.
- Installers/customers also have responsibilities to ensure compliance of their systems
- Barriers around this get hazy such as how much control should the utility have over the system?

PV benefits for Utilities

- Discussion of benefits for the utilities would be interesting to know if there was any other benefits and what are the net benefits for other parties

Financial Challenges

- **Who will pay for the PV systems?**
  - Utilities will make the customers pay either directly or indirectly
- Major question of equality between early adopters and late adopters and different socio economic status

PV system installation

- Utility can’t predict the output of the PV systems and can’t rely on them for power
- Who should regulate the installers industry?
- There is a mismatch between the residential systems (500,000 households according to the CEC) and load reducing the net benefit and increasing the problems. **Why are we encouraging the installation of these systems?**

Technical Integration challenges

- Underlying question with all of these is **how do we solve it** in a cost effective manner

Voltage

- Voltage problems raise an issue of compliance however it is under debate as to **whether the installer is responsible or the utility as it is the installers responsibility to choose appropriate consumer mains** (in line with AS3000)
- Many utilities aren’t compliant with old standards, will the new standards be enough to bring them in line?
- Can the voltage issues be blamed on solar or are the loads also a problem? i.e. will the tap changer option work?
- **How will we get reactive power from inverters** when customers are credited for real power?
• Who pays for network augmentation/studies?

System Stability
• How much control would you give to a utility over your inverter? (Cost implications)
• How much would you pay for storage
• Does the utility have the right to mandate that these be implemented?
• Why are PV systems different to load switching in and out?
• Whose responsibility is it to ensure the inverters are set to Australian standards and within protection specs? New AS4777 should fix this problem but what about existing installations?

Other issues
• Considered to be minor by the utility, open for discussion if anyone is interested

Limitation of PV systems
• Discussion into the limits some utilities are applying
  o The best way they see to deal with the issues
  o Cost implications for individuals
  o Customer backlash
  o What about solar farms?

Cultural Challenges
• Utilities are quite resistant to change in general and work is needed to change the culture and thinking to incorporate PV
  o At the same time it is still their responsibility to protect the network
• Smart meters in Victoria were rolled out as a utility innovation. If we are looking to match generation with load how do we do this and avoid consumer backlash?
• We are being discouraged from investing in the network due to PV impacts because of rising electricity prices. The consumer culture is generally one of distrust in the utilities as they can’t see any benefits from rising prices.
• Many utilities have different approaches a consistent practice is needed (being developed by the ENA but needs to be adopted).

Key Outcomes

High PV penetration is happening and can be dealt with technically
  o Who pays?
  o Utilities need financial incentives to be supportive
    o Cost pass through
    o Decoupling kWh sales from DNSP profits

Current grids are old, have high impedance and are being upgraded
  o How can this be coupled with development of grids suitable for high PV penetration?
PV projects can be caught in line waiting for upgrades
PV sector must provide DNSPs with information so they can reduce investment risk

Grids suitable for high PV need
- Visibility and control of PV system by utility
- Incentives for ancillary service provision – reactive power, frequency, voltage, fault ride through
- Forecasting systems
- Storage can assist

Connection processes currently uncertain, time consuming and variable
- Standardised conditions & procedures
- Guidelines
- Changes to some existing standards
- New standards, esp for larger inverters

Cultural and regulatory change needed
- Champions and solutions
- Means of off-setting network expenditure
- Processes to spread costs to later connections
- Information, demonstration, collaboration.

**Actions**

- Assist utilities in becoming comfortable with PV and in planning for the installation of commercial size systems in their networks
- Begin discussions with ENA on standardised approval and connection procedures for larger systems
- Work with Standards Committees on large-scale inverter standards
- Work with AEMC on distributed generation considerations in the NEM
- Arrange site visits and technical workshops with utilities to discuss specific items
Workshop Program:

10:00 am: Dr Muriel Watt, Chair, Australian PV Association  
*Current Australian PV Association activities and an update on the Australian PV market*

10:15 am: James Torpey, Director of Market Development, SunPower Corporation  
*Utility issues in Developing Large scale Solar PV in the U.S.*

11:00 am: The PV Industry Perspective:  
Daniel Ruoss, Solar Systems, Rodger Whitby, Ingenero  
*Developing large-scale PV projects in Australia*

11:30 am: Discussion – capturing PV benefits

12:00: *Lunch*

1:00 pm: Dr. Iain MacGill, CEEM, UNSW  
High PV Penetration in Electricity Grids, Australian Case Studies in Alice Springs (with PWC) and Carnarvon (with Horizon)

1:30 pm: The Networks Perspective:  
Simon Lewis  
*Integration issues and solutions in Australian networks*

2:30 pm: Discussion – minimising PV problems

3:30 pm: Close