On-Site Renewable Generation - Key Electrical Issues

Robert Mitchell
On-Site Generation Manager
(Client and project management)
Econnect

• “Energising renewables”
• Responsive: Econnect Consulting Ltd, Econnect Construction Ltd and Econnect Ventures Ltd businesses
• Offices in UK, Ireland, Australia & New Zealand
• Projects in over 20 countries
• Single on-site generators up to 1000MW offshore wind farm
• Wind Direct partnership: facilitating on-site generation from wind
Agenda

1. Background introduction to network and issues
2. Different types of generation
3. Key electrical issues
4. Example 1 – industrial site, no “spill”
5. Example 2 – rural site, mostly export
6. Practical issues
7. Summary of solutions
8. Conclusions & Questions
Power flows in a traditional network

Transmission-connected generators

Transmission system

Grid supply point

Distribution network

Customers
The changing network

Transmission-connected generators

Distribution network

Grid supply point

Wind farms

Biomass

Customers

CHP

PV Generators

Econnect Consulting
Renewable generation on the network

Transmission
- 275 kV
- 132 kV
- 132 kV
- 33 kV
- 33 kV
- 11 kV
- 11 kV
- 400 V

Distribution

Industrial on-site generation
- 500 MW
- 20 MW
- 5 MW
- 3.7 kW

Different capacities, different requirements!
On-site generation technologies

Asynchronous (induction) rotating machines

• Induction motor type design
• Typically simpler, cheaper, more reliable
• Historically direct-coupled
• Modern hybrids include Doubly Fed Induction Generators
• Not widely used as generator outside wind and small scale hydropower machines

Synchronous rotating machines

• Generated voltage synchronous with rotational speed
• Modern wind turbine versions include variable speed, full-scale converter coupled types with reactive power control
• Also used in CHP plants

DC current sources

• Inverter-coupled to ac network
• E.g. solar PV, fuel cell
• Normally associated with micropower …
• … but efficiencies and scales improving?
Key Electrical Issues

- **Equipment issues:**
  - Thermal limits
  - Reverse power flows
  - Fault level limits

- **Voltage control issues:**
  - Voltage rise issues
  - Voltage step issues
  - Voltage flicker issues
  - Harmonics
Thermal Limits

Overhead line
- Safety clearance

Transformers
- Overheating leads to insulation failure
- Reverse power flow capability?

Switchgear
- Overheating leads to insulation failure

Underground cables
- Overheating leads to insulation failure
Fault Level Limits

Contribution of current to a fault on network can lead to an overstressing of existing switchgear and is a major limiting factor to the connection of embedded generation.
Voltage Rise (Steady State)

Power Flow

Distribution Feeder

HV

LV Load

No Generation

Max

Min

Generation

Max

Min

Voltage Rise (Steady State)

Summer

Winter

Worst case: high generation, low demand
Voltage Step

![Diagram of power flow and voltage step]

- **Power Flow**
  - Direction from Generation to Load
  - Distinction between Summer and Winter conditions
- **Voltage Step**
  - Generation with Max and Min voltage levels
  - No Generation with Max and Min voltage levels

**Legend**
- Red: Summer
- Blue: Winter
Voltage Flicker

Visually noticeable:
Harmonics

- Ideal: perfectly sinusoidal waveform at 50 Hz
- But: some forms of generator use non-linear power electronic components to convert output to grid voltage -
  - introduces (limited) harmonic components to waveform
  - cumulative effects of local generation can:
    - create hotspots in transformers
    - prevent electronic equipment operating properly
Example 1: Industrial site, no export

- Single 660kW synchronous turbine generator on industrial site
- Turbine connected to own on-site 11kV ring with 3 substations around site
- High on-site load – no “spill”
- On-site ring connected to local distribution ring via 11kV feeders
Example 1: Private 11kV network

- Effects on private network primary concern
- Multiple connection options
- Generation small compared to existing on-site loads
- Issues may be acceptable on-site

- Effects on distribution network must still be considered e.g.
  - Voltage step at energising?
  - Fault contribution?

Issues must be addressed to meet on-site power quality requirements
Example 2: Rural network, full export

• 2 x 2MW on-site turbines

• Turbine connected directly to rural 11kV radial distribution network

• Low on-site local load, mostly export
Example 2: DNO 11kV network Issues

- Limited connection options
- Generation large compared to local demand
- Network not designed with such power flows in mind
- Reinforcement likely

Issues must be addressed to meet DNO requirements for export
Generally ...

• Case-by-case integration assessment required
  – Different connection options should be considered
  – Consider both on-site networks and DNO networks

• Urban networks
  – Tend to be “stronger”
  – More complex integration assessment required
  – Local loads – less of network affected

• Rural networks
  – Likely to be “weaker”
  – Export to remote loads – long length of network affected
  – More likely to require reinforcement
Practical Issues

- Connection options available?
- Step-up at turbine?
- Cable route – obstacles? – disruption?
- Type of connection? T-in, Loop-in, Busbar?
- Metering for ROCs?

DIFFERING CONNECTION OPTION COSTS?
Summary of solutions

• Generation side:
  – Addition of mitigating technology
  – Conditional constraints on export
  – Constraints on total generation capacity

• Network side (by DNO):
  – Reinforcement
  – Reconfiguring equipment or network

The future? Innovative solutions – for example …
Network product solution to voltage rise issues (Econnect Ventures Ltd) – Gen AVC™

GenAVC™

Remote terminal units

RTU

RTU
Conclusions

- Electrical issues can arise, and will need assessed
- Generation must comply with strict standards for grid connection
- Solutions can be usually be found!!