Network Distributed Generation Capacity Analysis Using OPF with Voltage Step Constraints

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Network Analysis for DG Integration

- Distribution Network Operators (DNOs) assess a wide range of technical factors in determining whether DG can be connected at a given site.
- Voltage rise, thermal limits, fault levels but also voltage step change, stability, etc., can place limits on size of DG connected.
- There has been a growing amount of (mainly academic) work trying to assess where DG should be optimally placed incorporating constraints, economics, etc.
Voltage Step Change

- Voltage step change is instantaneous drop in voltage with loss of DG
  - after AVR
  - before transformers react
- UK technical standards
  - ±3% planned, frequent events
  - ±6% for unplanned, infrequent
- DNOs applying different rules
- What impact does this have on ability to connect DG?
Use of Optimal Power Flow

- Edinburgh has extensively researched use of AC OPF to find maximum capacity of DG available within the limits of the network
  - voltage rise, thermal limits, fault levels
  - voltage step change limits included for the first time
- Step change limits are modelled like line outage security constraints
  - post-outage power flows are a constraint
  - limit placed on change in voltages before and after outage of a DG
- Large combinatorial problem with high locational interdependency
Example

- DG placed at three buses
  - power factor important for capacity
- Constraints applied
  - Case 1: Thermal limits and steady state voltages within ±3%
  - Case 2: As above but with voltage step change limits of ±3%
- Worst case conditions of maximum generation and minimum load
Example

Case 1

Constrained by upper voltage limits at buses 22 & 25

Case 2

Constrained by voltage step limits on loss of DG at buses 23 & 26

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Results

• What voltage step limits should apply?
  – how does the allowable voltage step affect capacity?

• Reanalysis with different allowed voltage step:
  – At very tight step constraints voltage step is binding
  – As it is progressively relaxed voltage and thermal constraints dominate
  – Choice of step limit important for capacity
Conclusions

- Voltage step change limits are also regarded as a constraint on DG penetration
- Developed a bespoke OPF to assess their impact
- DG power factor has a big influence
- Progressive relaxation lowers their impact
- UK proposals to increase limits to 10% will allow greater penetrations of DG