Overview and issues addressed

- Background
  - General control and interconnection issues
  - Interconnection requirements
- Grid interconnection and relevant standards
  - Distribution systems standards
  - Transmission system requirements
- Typical grid codes - transmission
  - Power
  - Voltage and frequency
  - Low voltage ride through
- Concluding comments
Justification for standardization efforts

• Context
  • Large scale wind integration getting more and more interest
  • Need felt by new players for harmonized interconnection standards and grid codes

• Grid integration effort - purpose
  • Develop electrical interconnection guidelines and standards with the aim of building consensus among stakeholders on Distributed Energy Resources (DER) and alternative and renewable energy system (wind, photovoltaic) interconnection to the grid

Fundamental DG issues

• Connection options
  • Distribution network connection, low (LV) and medium voltage (MV), up to 69 kV, or even 110 kV
  • Transmission network connection

• Power system impacts
  • Distribution: typically radial systems
  • Transmission system: typically meshed systems

• Differing responsibilities and concerns
  • Distribution: power quality and short circuit levels
  • Stability and voltage support of the transmission grid

• Operating options
  • Anti-islanding: smaller units (IEEE 1547)
  • Grid support: DG operates as conventional generators (trend)
Standards and practices

Classes of standards, regulations and requirements:
- Generally applicable standards (IEEE, IEC, …): design, performance and testing; connection requirements
- Specific standards (photovoltaic, wind turbines, …): design, performance and testing; connection requirements, electric and mechanical performance
- Utility interconnection regulations (issued by regional grid operators as conditions for connecting DER or IPP to the transmission or distribution grid)

Standards - general

- Generally applicable standards for the connection of electric equipment to the electric grid.
  - IEEE in North America and IEC in Europe, cover harmonic interference and electrical impacts on the grid.
- Most commonly used are the IEEE 519 and the IEC 61000 series.
  - IEEE Standard 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
  - IEC 61000-3 Series: Electromagnetic compatibility (EMC), in particular Part, Limits on harmonics, distortion, voltage fluctuations, ..
DR Standards – distribution systems

• Distributed resources (DR) standards
  • IEEE 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems and applies to DR less than 10 MW

• Technology specific standards
  • Photovoltaic power systems: IEEE 929 and work under IEC TC82
  • Wind: IEC 61400, work under IEC TC88, AWEA
  • MicroPower Connect Interconnection Guideline, for inverter-based micro-distributed resources (DR) systems (600 volt or less), a Canadian initiative.

IEEE 1547 – Scope and on-going work

• Standard for Interconnecting DR with Electric Power Systems - Guide For Interconnection System Certification, associated with the development of a series of application guides and standards:
  • P1547.1 Draft Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
  • P1547.2 Draft Application Guide for IEEE P1547 Draft Standard for Interconnecting Distributed Resources with Electric Power Systems
  • P1547.3 Draft Guide for Monitoring, Information Exchange and Control of DR Interconnected with EPS
  • Others
IEEE 1547 – Content

- Definitions
- Technical specifications and requirements
  - General:
    - Response to abnormal conditions
    - Power quality
    - Islanding
- Test specifications and requirements
  - Design test
  - Production tests
  - Interconnection installation evaluation
  - Periodic interconnection tests

IEEE 1547 – Technical specifications

- Voltage regulation: the DR does not actively regulate the voltage at the PCC.
- Integration with area EPS grounding: the DR does not cause overvoltages or affect the ground protection.
- Synchronization: the DR shall parallel with the Area EPS without causing voltage fluctuations greater than 5 % and meet flicker requirements.
- Impact on network: the DR does not affect the normal operation of the Area EPS equipment.
- Inadvertent energization of Area EPS is not allowed.
- Monitoring and isolation requirements
Requirements – large installations

- Usually based in part on conventional generation
- Controllable power factor between 0.95 inductive and 0.95 capacitive, typical
- External tripping control
- After fault conditions, specified growth of active power
- Wind farms with a power output of more than 100 MW to act like a conventional power station, that is providing:
  - control of active power on demand
  - providing spinning reserve for frequency control
  - providing reactive power control

Wind energy in Canada – grid connection
Grid codes examined - typical

- Utilities – transmission and distribution connection – specific requirements - sample
  - Quebec, wind, 44 kV and above, specific
  - Alberta Elect. Sys. Oper. (AESO), draft, wind, 138 kV and above, specific & IEEE 519
  - BC Hydro, up to 35 kV, specific & IEEE 519
  - Saskatchewan, up to 25 kV, specific
  - Manitoba, up to 25 kV, specific & IEEE 519
  - Ontario Energy Board, up to 50 kV, specific & IEEE 519 and 1547
- Alternately, with the same utilities, for transmission interconnections, conventional requirements are usually applicable.

Issues and parameters specified

- Power
  - Power control
  - Power factor and reactive power capability
- Voltage
  - Voltage control
  - Voltage range – continuous operation
  - Voltage range – transient operation
  - Voltage dips – no tripping
- Frequency
  - Frequency control
  - Frequency range – continuous operation
  - Frequency range – transient operation
Power factor and reactive power

- Power factor (pf)
  - Lead: 0.95 to 0.95
  - Lag: 0.9

- Reactive power (Q)
  - Proposed 1
  - Proposed 2

Typical operating frequency ranges

- Frequency (f)
  - Proposed 2
  - Trip

- Time:
  - 0.3s
  - 2s
  - 10s
  - 1min
  - 10min
Typical operating voltage ranges

<table>
<thead>
<tr>
<th>V (pu)</th>
<th>Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td></td>
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<tr>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

Trip

Time (s)

0.2 1 2 10 300

Low voltage ride through - AWEA

<table>
<thead>
<tr>
<th>V_{cc} (pu)</th>
<th>Wind Generator may Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>0.9</td>
<td>No Trip</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Time (s)

0.0 0.6 3.0
Grid codes – analysis and comparisons

Generally similar requirements with variations on:

- Power factor: variable, within the range 0.90 lead to 0.90 lag, typical 0.95 lead to 0.90 lag
- Voltage range - continuous operation: variable, within the range 90 % to 110 %
- Voltage range - transient operation - tripping: variations in levels and durations, 60 % to 140 %, and to 300 s
- Frequency range – continuous operation: variable, widest 59.4 to 60.6 Hz
- Frequency range – transient operation - tripping: variable in levels and duration, widest 55.5 and 61.7 Hz, and up to 11 min

Global and regional harmonization efforts

- IEC group TC8, System aspects of electrical energy supply:
  - Purpose: to develop international standards needed to facilitate the functioning of electricity supply systems, and to achieve the best balance between cost and quality for the users of electrical energy
  - Ad-Hoc Group 2: Connection to Electricity Supply Systems
  - Participants: Europe, North America (inc USA and Canada), Australia, Japan, …
- Canada efforts other than international partnerships
  - Canadian Wind Energy Association (CANWEA) – in collaboration with AWEA
  - Canadian Standards Association (CSA)
  - Canadian Program on Decentralized Energy Production
Technical organizations - contributions

• Forums for discussing general issues and developing summary reports and application guidelines, particularly related to DR:
  • IEEE Power Engineering Society Distribution Subcommittee, Working Group on "Distributed generation integration"
  • IEEE Power Engineering Society HVDC and FACTS Subcommittee, Working Group on "Major grid integration", including wind energy
  • CIGRE Study Committee C6 on "Distribution Systems and Dispersed Generation", with a number of Working Groups, including: "Connection and Protection Practices for Dispersed Generation"

Conclusions

• Situation regarding standardization and harmonization of grid interconnection requirements:
  • Significantly advanced in low and medium voltage equipment and systems
  • Efforts may be beneficial for larger systems connected to the transmission grid
• Direct benefits to manufacturers
  • Standardization of products (reduction in engineering costs)
  • Streamlining impact studies
Conclusions - continued

• Other benefits of harmonization efforts:
  • Dialogue between utilities, and between utilities and manufacturers can contribute to a better integration of DR
  • Promotion of benefits of wind energy and other alternate energy sources with impact on reduction in greenhouse gases, on grid support and on the enhancement of grid reliability and vulnerability
  • Technology development and the resulting increase in the use of DR and the number of installations

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