Modeling Renewable Generation for Short Circuit Analysis

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April 6, 2019
Agenda

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• Overview of Wind Generation
  – Type 1
  – Type 2
  – Type 3
  – Type 4
  – Type 5
• Solar Generation
• CAPE and OneLiner Implementation
• Takeaways
Background

• More renewable generators are being integrated into the grid at a faster pace compared to a few years ago
• Technology has advanced significantly that wind and solar generators can output significant power to the grid to supplement and even replace conventional generators
• Previous mindset of having these renewable generation to trip off for any disturbance in the grid is changed because of the renewable generation is now depended upon to serve firm load
• With these generators riding through disturbances, they now contribute to short circuit duty
Overview of Wind Generation

- Wind generators have been classified into 5 types:
  - Type 1 – Squirrel Cage Induction Generator
    - First types of wind turbines to generate electricity for grid applications
    - Used to be set to trip off for grid disturbances i.e. no contribution to short circuit
    - Must now comply with low voltage and low frequency ride through
    - With ride through requirements, the contribution to the fault of these generators is equivalent to Xd' (locked rotor current)
Overview of Wind Generation

- Type 2 – Squirrel Cage Wound Rotor Induction Generator with External Resistance
  - Newer type of wind turbines but concurrently installed with type 1 wind generators
  - Contribution to the fault is similar to Type 1 with an added rotor resistance
Overview of Wind Generation (cont.)

- Type 3 – Double Fed Asynchronous Generator
  - Newer type of generators that have been popular and are part of the newer installs
  - Short circuit contribution depends on the mode of operation (with and without crowbar)
    - With Crowbar – contribution to the fault is $X_d'$
    - Without Crowbar – contribution to the fault is between 1.1 p.u. to 2.5 p.u. of the rated current of the generator
Overview of Wind Generation (cont.)

- Type 4 – Full Power Converter Generator
  - Most prolific type of wind turbine for the newest installs
  - Short circuit contributions are limited to around 1.1 p.u. to 1.5 p.u. of the rated current of the generator
  - At the moment, these are programmed to provide balanced positive sequence symmetrical current regardless of the type of fault
Overview of Wind Generation (cont.)

– Type 5 – Synchronous Generator mechanically connected through a torque converter
  • Newest wind turbine design
  • Short circuit contribution is the same as a conventional synchronous generator as a voltage source behind a series impedance (X”d, X’d, or Xd)

One thing that must be stressed:

The data from the manufacturer and the generator owner is very important because due to the different manufacturers’ design short circuit contribution can be vastly different and to know how it is programmed is also important especially for Type 4.
Solar Generation

• Inverter based solar generators are identical to Type 4 wind generator from a grid perspective
• The only difference is the “prime mover”
• Short circuit contribution is limited to around 1.1 p.u. to 1.5 p.u. of the rated current of the generator
CAPE and OneLiner Implementation

• IEEE Power System Relaying and Control Committee work Group C24 has been tasked to work with commercial fault calculation programs to more accurately model fault behavior of type 3 and type 4 wind turbines.

• The work group has the following recommended data tables so that it can be used in the fault calculation programs:
  – Item 1: Specify the fault type
  – Item 2: Specify if the fault response is time dependent. If so, complete a separate table for each time frame that may be considered “steady state” for a phasor solution
CAPE and OneLiner Implementation (cont.)

- Item 3: Specify the voltage signal that the control system responds to. e.g. positive sequence, phase to phase voltages, or other. The voltage values in the first column of the table can be expressed as:
  - Positive sequence voltage
  - The highest value of line voltages VAB, VBC or VCA
  - The lowest value of VAB, VBC or VCA
  - The average value of VAB, VBC or VCA
  - Other

- Item 4: Complete the following table to specify the response of the current control system at various per unit values of the measured voltage (one for each time frame longer than 1 cycle). Similar tables should be provided for time frame 2 and additional time frames if necessary. Power factor angle is positive if the reactive power is generated, and negative if absorbed.
CAPE and OneLiner Implementation (cont.)

<table>
<thead>
<tr>
<th>Time frame 1 (seconds or cycles)</th>
<th>Fault Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>V (as specified in item 3) (pu)</td>
<td>Positive sequence current (pu)</td>
</tr>
<tr>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td></td>
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<tr>
<td>0.7</td>
<td></td>
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<tr>
<td>0.6</td>
<td></td>
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<tr>
<td>0.5</td>
<td></td>
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<tr>
<td>0.4</td>
<td></td>
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<tr>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

- Item 5: It is realized that the response of the control system (and consequently the fault response) depends on the control settings of the converter and may vary depending on those. The manufacturers may provide a separate table (or sets of tables) for different control modes of the power source.
CAPE and OneLiner Implementation (cont.)

OneLiner’s Type 3 Implementation
CAPE and OneLiner Implementation (cont.)

OneLiner’s Type 4 Implementation

![Converter-Interfaced Generator](image1)

![Advanced Parameters of Converter-Interfaced Generator](image2)
CAPE and OneLiner Implementation (cont.)

CAPE’s Type 3 and Type 4 Implementation
Sources of Information


Draft copy of “Modification of Commercial Fault Calculation Programs for Wind Turbine Generators” IEEE Paper prepared by Power System Relaying and Control Committee
Takeaways

• With the requirements of under voltage and under frequency ride through, renewable generators will be contributing to short circuit duty
• Wind and Solar generators have specific data to be aware of depending on its type
• Data is important because there is no “one size fits all”
• CAPE and OneLiner have been working to integrate the latest modeling practices
• SCMWG needs to weigh in on the best practices recommendation
Questions? Comments?