Generic parameterization of the DER_A model

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DER_A Model

Voltage control path…

- The values below are recommended as defaults
- Volt – Var and dynamic voltage support are not IEEE Std 1547™ – 2018 default enabled functions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IEEE 1547-2003 Default</th>
<th>IEEE 1547a-2014 Default</th>
<th>CA Rule 21 Default (similar to IEEE Std 1547-2018 Cat. III)</th>
<th>IEEE Std 1547-2018 Category II Default</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
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<td>-99.0</td>
<td>-99.0</td>
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<tr>
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<td>99.0</td>
<td>99.0</td>
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<td>0.0</td>
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</tbody>
</table>
## Frequency support functionality (IEEE Std 1547™ – 2018 Clause 6.5.2.7.2)

- Overall, fairly straightforward
- Open loop frequency response time constant of 5s

<table>
<thead>
<tr>
<th>Parameter</th>
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<th>IEEE Std 1547-2018 Category II Default</th>
</tr>
</thead>
<tbody>
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<td>20.0</td>
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<td>Dup</td>
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<td>20.0</td>
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<td>-99.0</td>
<td>-0.0006</td>
<td>-0.0006</td>
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<tr>
<td>fbd2</td>
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<td>0.0006</td>
<td>0.0006</td>
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<tr>
<td>femax</td>
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<td>99.0</td>
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<td>-99.0</td>
<td>-99.0</td>
</tr>
<tr>
<td>Pmax</td>
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<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Pmin</td>
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<td>0.0</td>
<td>0.0/-1.0</td>
<td>0.0/-1.0</td>
</tr>
<tr>
<td>dpmax</td>
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<td>99.0</td>
<td>99.0</td>
<td>99.0</td>
</tr>
<tr>
<td>dpmin</td>
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<td>-99.0</td>
<td>-99.0</td>
<td>-99.0</td>
</tr>
<tr>
<td>Tpord</td>
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<td>0.02</td>
<td>5.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>
Rules of thumb for generic trip parameters

- Assumes voltage drop from substation to tail.
- Parameter values for other voltage profiles is still a research question

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IEEE 1547-2003 Default</th>
<th>CA Rule 21 Default (similar to IEEE Std 1547-2018 Cat. III)</th>
<th>IEEE Std 1547-2018 Category II Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>vl0</td>
<td>0.89 - (V_{sub0} − V_{tDER_A0})</td>
<td>0.89 - (V_{sub0} − V_{tDER_A0})</td>
<td>0.71 - (V_{sub0} − V_{tDER_A0})</td>
</tr>
<tr>
<td></td>
<td>OR</td>
<td>OR</td>
<td>OR</td>
</tr>
<tr>
<td></td>
<td>0.49</td>
<td>0.49</td>
<td>0.44</td>
</tr>
<tr>
<td>vl1</td>
<td>0.89</td>
<td>0.89</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>OR</td>
<td>OR</td>
<td>OR</td>
</tr>
<tr>
<td></td>
<td>0.50 + (V_{sub0} − V_{tDER_A0})</td>
<td>0.50 + (V_{sub0} − V_{tDER_A0})</td>
<td>0.45 + (V_{sub0} − V_{tDER_A0})</td>
</tr>
<tr>
<td>vh0</td>
<td>1.1 OR 1.2</td>
<td>1.1 OR 1.2</td>
<td>1.1 OR 1.2</td>
</tr>
<tr>
<td>vh1</td>
<td>1.1 − (V_{sub0} − V_{tDER_A0})</td>
<td>1.1 − (V_{sub0} − V_{tDER_A0})</td>
<td>1.1 − (V_{sub0} − V_{tDER_A0})</td>
</tr>
<tr>
<td></td>
<td>OR</td>
<td>OR</td>
<td>OR</td>
</tr>
<tr>
<td></td>
<td>1.2 − (V_{sub0} − V_{tDER_A0})</td>
<td>1.2 − (V_{sub0} − V_{tDER_A0})</td>
<td>1.2 − (V_{sub0} − V_{tDER_A0})</td>
</tr>
<tr>
<td>tvl0</td>
<td>(0.1-1.5) OR 0.16</td>
<td>10.0 OR 1.5</td>
<td>5.0 OR 0.16</td>
</tr>
<tr>
<td>tvl1</td>
<td>(0.1-1.5) OR 0.16</td>
<td>10.0 OR 1.5</td>
<td>5.0 OR 0.16</td>
</tr>
<tr>
<td>tvh0</td>
<td>(0.1-1.0) OR 0.16</td>
<td>10.0 OR 0.16</td>
<td>1.0 OR 0.16</td>
</tr>
<tr>
<td>tvh1</td>
<td>(0.1-1.0) OR 0.16</td>
<td>10.0 OR 0.16</td>
<td>1.0 OR 0.16</td>
</tr>
<tr>
<td>Vfrac</td>
<td>0/(0-0.8)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Assumes voltage drop from substation to tail.
Parameter values for other voltage profiles is still a research question.
Concept behind generalization

**In a distribution feeder**

- The first inverter to trip on the feeder is likely located towards the tail.
- The last inverter to trip is likely located towards the head.
- The first inverter would trip when the tail of the feeder has a voltage below the individual inverter trip threshold (0.88pu in our case).
- The last inverter would trip when the head of the feeder has a voltage below the individual inverter trip threshold. (0.88pu in our case)

**In positive sequence**

- Assuming DER_A bus represents the tail of the feeder (at present, this is a big assumption!).
- Assuming a net downward trend in voltage profile across the feeder (even with regulators and capacitor banks):
  - vl1 in DER_A = 0.89pu (Indicates the start of tripping of the first inverter at the tail)
  - vl0 in DER_A = 0.89 - v_{feeder-drop} (indicates the end of tripping with the last inverter at the head)
  - v_{feeder-drop} is usually between 0.02pu – 0.08pu
Options for trip settings

<table>
<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td>vl0</td>
<td>0.89 - (Vsub0 – VtDER_A0)</td>
</tr>
<tr>
<td></td>
<td>OR 0.49</td>
</tr>
<tr>
<td>vl1</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>OR 0.50 + (Vsub0 – VtDER_A0)</td>
</tr>
<tr>
<td>vh0</td>
<td>1.1 OR 1.2</td>
</tr>
<tr>
<td>vh1</td>
<td>1.1 – (Vsub0 – VtDER_A0)</td>
</tr>
<tr>
<td></td>
<td>OR 1.2 – (Vsub0 – VtDER_A0)</td>
</tr>
<tr>
<td>tvl0</td>
<td>(0.1-1.5) OR 0.16</td>
</tr>
<tr>
<td>tvl1</td>
<td>(0.1-1.5) OR 0.16</td>
</tr>
<tr>
<td>tvh0</td>
<td>(0.1-1.0) OR 0.16</td>
</tr>
<tr>
<td>tvh1</td>
<td>(0.1-1.0) OR 0.16</td>
</tr>
<tr>
<td>Vrfrac</td>
<td>0/(0-0.8)</td>
</tr>
</tbody>
</table>

Option 1:
- If all the DERs on the feeder have a trip threshold as 0.88pu
  - vl1 = 0.89pu; vl0 = 0.89 - (Vsub0 – VtDER_A0); tvl0 = tvl1 = between 0.1s and 1.5s.

Option 2:
- If all the DERs on the feeder have a trip threshold of 0.5pu.
  - vl1 = 0.50 + (Vsub0 – VtDER_A0); vl0 = 0.49; tvl0 = tvl1 = 0.16s.

Option 3:
- If some DERs have a threshold of 0.88pu while others have a threshold of 0.5pu,
  - vl1 = 0.89; vl0 = 0.49pu; tvl0 = tvl1 = between (0.1s – 1.5s) and 0.16s respectively.

Option 4 (invalid):
- As vl1 should be greater than vl0.

There is a further complexity: If total amount of DER is around the feeder hosting capacity, then (Vsub0 – VtDER_A0) can be halved – This is still a heuristic and does not yet have a solid analytical/mathematical basis.
Fraction of tripping/recovery

- In all cases, $V_{rfrac} = 0.0$, unless more sophisticated information on DER deployment is available to differentiate between legacy ($V_{rfrac} = 0.0$) and modern DER ($V_{rfrac} = 1.0$).
- $V_{rfrac}$ can hold a value between 0.0 and 0.8 only when there are inverters on the feeder which are a mix of two sets of standards:
  - one set is based upon either IEEE Std. 1547-2003 or IEEE Std. 1547a-2014,
  - other set is based upon either CA Rule 21 or IEEE Std. 1547-2018.
  - value of $V_{rfrac}$ will be the percentage of inverters that belong to the second set.
  - As CA Rule 21 and IEEE Std. 1547-2018 are relatively newer standards, it can be expected that for now, $V_{rfrac}$ can be set to 0.0
Example simulation results: Voltage trip thresholds for two feeders – 0.88pu for 0.1s & 1.2pu for 0.1s

- Detailed distribution feeder simulation
- Positive sequence DER_A model
### Frequency trip characteristics

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>fl</td>
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<td>59.5 OR 57.0</td>
<td>58.5 OR 56.5</td>
<td>58.5 OR 56.5</td>
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<tr>
<td>fh</td>
<td>60.5</td>
<td>60.5 OR 62.0</td>
<td>61.2 OR 62.0</td>
<td>61.2 OR 62.0</td>
</tr>
<tr>
<td>tfl</td>
<td>0.16</td>
<td>2.0 OR 0.16</td>
<td>300.0 OR 0.16</td>
<td>300.0 OR 0.16</td>
</tr>
<tr>
<td>tfh</td>
<td>0.16</td>
<td>2.0 OR 0.16</td>
<td>300.0 OR 0.16</td>
<td>300.0 OR 0.16</td>
</tr>
</tbody>
</table>

- As all under frequency trip thresholds are at or below today’s UFLS settings, it is expected that in a well conditioned interconnection operating condition, these relays should not trip.
- The values in green are recommended to be used
Remaining parameters...

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<th>IEEE Std 1547-2018 Category II Default</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
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<td>2.0</td>
</tr>
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<td>0.02</td>
</tr>
<tr>
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<td>0.0</td>
<td>0.1</td>
<td>0.1</td>
</tr>
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<td>10.0</td>
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</tr>
<tr>
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<td>0.25</td>
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<td>1/0</td>
</tr>
</tbody>
</table>

- rrpwr = 2.0 to accommodate a requirement of return to 80% of rated power in 0.4s
- vpr = 0.3pu to accommodate a requirement in IEEE Std. 1547 – 2018 Clause 6.5.1 which is paraphrased as:
  - frequency tripping should occur when fundamental-frequency rms component of voltage on any phase is greater than 30% of nominal
Ongoing research work…

- Evaluation of trip parameters on other feeders from across the country in order to make firm the generic parameters
- Evaluation of impact of load dynamics
- Evaluation of smart inverter functionality
Together…Shaping the Future of Electricity