Low-cost Protection System for Distribution Grids with Distributed Generation

Nadezhda Davydova

Background

- High penetration of distributed generation in distribution grids may cause malfunctioning of conventional protection systems.
- The main challenges that conventional protection systems face:
  - bidirectional power flows,
  - decrease in the level of short circuit currents due to high penetration of converter-based distributed generation,
  - requirement for high-speed fault localization,
  - different fault current levels in connected and islanded operations of microgrids.
- Solution: development of a reliable cost-efficient protection system for active distribution grids.

Proposed Protection of Distribution Lines

- Simultaneous protection of all lines connected to medium voltage busbars of a given substation.
- Each protected line has a current transformer (CT) and circuit breaker (CB), both installed at the substation.
- Local current measurements from all protected lines are inputs.
- Based on measurements, protection system identifies faulted line within its protection zone and performs a one-sided trip of the line.
- Protection is based on Traveling Wave Theory and employs Discrete Wavelet Transform (DWT) and Machine Learning techniques.
- Overview of the main blocks of the protection system:
  - MT block transforms phase currents into modal components to facilitate the analysis of wave transients.
  - WE block extracts fault-generated traveling waves that contain information on the origins of the transients using DWT.
  - DD block detects the direction of the fault with respect to the protection terminal’s location.
  - FL block determines whether the fault is internal or external employing Machine Learning techniques.

Novelty

- Protection system requires only local current measurements.
- Simultaneous protection of all lines interconnected at a busbar.
- The underlying approach for DD block is based on analyzing circuit models that describe traveling wave behavior at the protection terminal’s location for all possible fault directions and selecting the one that matches the input data the best.

Experimental Setup

- IEEE 34 bus test distribution system with different types of distributed generation.
- The protection terminals are installed on all busbars of the grid.
- Simulation scenarios include normal operation of the grid, switching transients, all types of faults occurring at various time moments and locations in the grid.

Simulation Results and Conclusions

- The results are provided for the protection terminals installed on buses 834, 842, and 844.
- The table presents the results of joint operation of WE and DD blocks for phase-A to ground fault and 90° inception angle.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>at 844</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 842</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 834</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figures illustrate the principle behind the DD algorithm for different number of protected lines (bus 834 and 842).
- Simulation scenario: fault in the middle of line 2 (phase-A to ground, 90°).
- The protection system requires only local current measurements, which eliminates the problem of the voltage circuits’ loss and makes it a low cost solution due to the lack of communication links.
- Proposed protection system addresses the challenges imposed by active distribution grids and operates reliably in case of any number of protected lines, fault types, and grid modes.

Part of IEEE 34-bus Test System