Modeling Stochastic Contingency Reserve Activation and Response Deficiency


WIRL (Wind Integration Research Lab)
University of Washington

Abstract

Recent, unprecedented increases in wind penetration pose new challenges to maintaining good control performance in power systems. The stochastic nature of wind power creates an incentive to treat control resources as stochastic. This work presents a stochastic, time-dependent model of contingency reserve (CR) activation that is based on system behavior expected by the NERC and WECC disturbance control performance standards. The model quantifies CR activation as a statistical combination of probability density functions (PDFs) that represent CR response deficiencies and generation outage probabilities. This work also formulates an algorithm for determining the CR response deficiency PDFs in real-time from observed energy management system data. The proposed model has multiple applications such as a deterministic or stochastic unit commitment, system adequacy evaluation, contingency reserve margins, and contingency reserve allocation.

Problem Statement

How can we efficiently and accurately model the many random failures that may occur during the course of CR activation which contribute to uncertainty in Contingency Reserve Response?

Solution Method

1. Compute CR Deficiency samples of individual generators when deploying CR after a contingency occurring at $t_c$.
   - Determine desired CR from EMS & market data
   - Determine actual CR from measured generator output after $t_c$

2. Build stochastic models (PDFs) of CR Deficiencies from multiple samples
   - $P_{CRDD10}$ and $P_{CRDD15}$

3. Maintain accurate PDFs as the system changes over time with:
   - Confidence Intervals on PDF mean and variance
   - Rolling Buffer to replace obsolete samples with new samples

Good vs. Poor Contingency Reserve Response

<table>
<thead>
<tr>
<th>Time Interval (min)</th>
<th>$P_{ACR}(t)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0 \leq t &lt; 10$</td>
<td>0</td>
</tr>
<tr>
<td>$10 \leq t &lt; 15$</td>
<td>$P_{ACRDD10}$</td>
</tr>
<tr>
<td>$15 \leq t &lt; 105$</td>
<td>$P_{ACRDD10} \oplus P_{ACRDD15}(t)$</td>
</tr>
<tr>
<td>$105 \leq t \leq 300$</td>
<td>$P_{ACRDD10} \oplus P_{ACRDD15}(100) \oplus P(t-105)$</td>
</tr>
</tbody>
</table>

Conclusions

A holistic model of the stochasticity of contingency reserve activation and response is presented. The model is based on real-time EMS data and individual generator outputs. It maintains accuracy with confidence intervals and rolling buffers. A specific application to a deterministic unit commitment is presented, but the model can have multiple applications.

Future Directions

- Explicitly determine this model’s use in other applications, e.g. reliability assessment.
- Work with a utility / control area to:
  - Test the use of this method in a real system
  - Compare the usefulness of this model with e.g. an ACE-based model of contingency reserve activation

Acknowledgements

This project was funded by the Pacific Northwest National Laboratory (PNNL). We thank Yun Makarov, Pavel Etingov, Henry Huang, and Kevin Schneider at PNNL for helpful discussions regarding realistic contingency reserve activation and response models and for supplying a capacity outage probability model.

References