PMU Error Impact on Measurement-Based Applications

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Project Team

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Objective and Accomplishments

• Overall Project Objective
  Assess the impact of the measurement errors on synchrophasor based applications

• Looking Back (July 2014 - June 2015)
  – Completed error impact study for four (4) applications
  – Three (3) Related Best Papers at 2015 PES General Meeting

J. Zhao, L. Zhan, Y. Liu, H. Qi, J. R. Garcia, and P. D. Ewing, “Measurement accuracy limitation analysis on synchrophasors”, IEEE PESGM 2015. (This study performed in 2014)
FY15 Accomplishments and Deliverables

• **Effect of renewable sources on measurement accuracy**
  – Study impact of wind turbine blade shadow effect (Mar 2015)
  – Study impact of harmonics from PV inverters (July 2015)

• **GPS loss statistics and impacts**
  – GPS loss rate from historical PMU and FDR data (Aug 2015)
  – Impact of GPS loss on time drift and measurement error (Aug 2015)
  – GPS loss distribution in relation to time and location (Oct 2015)
Risks and Thoughts for Future

- **Risks or uncertainties** - No known risks or uncertainties
- **Early thoughts on follow-on work**
  - Impact of communication delay (FY16)
  - Impact of data loss (FY16)
  - Evaluate the benefit of increased data reporting rate (FY17)
  - Re-visit the distribution level measurement accuracy limits (FY17)
Selected Applications

• PMU applications for this study

- Event Location
- Oscillation Detection
- Islanding Detection
- Dynamic Line Rating
Error Sources Used in the Study

• **PMU Error**
  - IEEE Std C37.118.1-2011, C37.118.1a-2014
  - Phase angle: 0.57° (0.6°) based on 1% TVE
  - Frequency error: 0.005 Hz

• **Instrument Channel Error**
  - PT, CT, CCVT, Cable combined error
  - -0.2° to -1.0° for most cases

Methodology

• Assumption
  o Frequency error: ±0.005 Hz (most PMUs are better)
  o Angle error
    - PMU part: ±0.6° (most units are better)
    - Instrumentation channels -1.0° (maximum)
      This number varies with installation situation and impacts only applications using absolute angles.

• Approach
  o Assume the maximum error
  o Find the worst case
Angle-Based Event Location

▲: first responding FDR
●: event location range
●: possible power plants

2010/01/03 13:03:43(UTC) Generation Trip

- CaMbWinnipeg665
- UsCtDanbury666
- UsFlU663
- UsIlChicago620
- UsMaBoston684
- UsMaNeisco682
- UsMiCalvin679
- UsMiWayneState621
- UsMoKansasCity616
- UsMoMst624
- UsMsMissi662
- UsNjNerc678
- UsNyLeroy667
- UsOhChillicothe670
- UsOhColumbus687
- UsTxTexasTech683
- UsVaAri661
- UsVaBlacksburg656
- UsVaNewportNews668
- UsVaRichmond601
- UsVaRvcs686
- UsWlMadison649
- UsWvCharleston688
How Error Impact the detection order

• An Example

![Graph showing time and angle with error ±0.6°]
Most Scenarios Unaffected
Oscillation Detection: Approach

- Phase angle based two-threshold method

\[ |A(\text{max}) - A(\text{min})| > \text{Th2} \]

\[ \text{Th1} \]

\[ 5 \text{ S} \]
Islanding Detection: Frequency Based

Islanding Taking Place

Error may affect accuracy if < 1 second detection time is required at 30p/s rate. Time delay is required for false event rejection.
Dynamic Line Rating

- PMUs provide $V$ and $I$ phasors on both ends
- Consider only angle error in $V$ and $I$
- Algorithm shown in references below

Influence of Different Factors

Wind Speed

Ambient Temperature

Solar Heat
Error Impact

Summer
Errmax: 45.87%
## Conclusion

<table>
<thead>
<tr>
<th>Application</th>
<th>Effect</th>
<th>Significance</th>
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<tbody>
<tr>
<td>Event location</td>
<td>A small number of cases show impact</td>
<td>Minor impact</td>
</tr>
<tr>
<td>Oscillation detection</td>
<td>Problem only for small magnitude cases</td>
<td>Threshold dependent</td>
</tr>
<tr>
<td>Islanding detection</td>
<td>Safe for detection time &gt; 1 second</td>
<td>Detection time dependent</td>
</tr>
<tr>
<td>Dynamic line rating</td>
<td>Potential to introduce large errors</td>
<td>Very sensitive</td>
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</tbody>
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Additional Information
Event Location: A Brief Introduction

- **Angle-Based Event Location**
  - ▲: first responding FDR
  - ☐: event location range
  - ●: possible power plants
Impact of Error Depends on Thresholds

• False detection
Impact of Error Depends on Thresholds

- Failed detection

![Diagram showing impact of error on thresholds](image-url)
Error Impact

Winter
Errmax: 22.87%