Using Synchrophasors for Controlled Islanding

A Prospective Application in the Uruguayan Power System

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Follow up

- Last year’s panel on “Wide-Area Early Warning”, GM San Diego 2012.
- Voltage Instability Alarm by Real-Time Predictive Indicators – S. Corsi & G. Taranto
Presentation Outline

• Motivation and objectives
  • The Uruguayan Power System

• Out-of-Step protection

• Strategies Utilized for load shedding and controlled islanding

• Conclusions
Motivation

- The Uruguayan Power System
  - Peak load of 1.7 GW (80% in great Montevideo)
  - Gen. capacity 2.6 GW (53% hydro, 47% thermal)
- Hydro generation mostly in the North
- Thermal generation concentrated in South
Motivation (cont.)

- Outages in two 500 kV lines (Palmar – Montevideo)
- Can lead the system to a complete blackout
- Fast controlled N-S separation by opening the 150 kV network, plus fast load shedding in the South
Objective

- The comparison of three emergency protection strategies to maintain the system in operation with the smallest amount of load curtailment.
Distance Protection and Power System Stability

\[ \bar{Z} = \bar{V}_C \frac{k[(k - \cos \delta) - j \sin \delta]}{(k - \cos \delta)^2 + \sin^2 \delta} - \bar{Z}_A \]

\[ k = \frac{|E_A|}{|E_B|} \]
Power Swing Detection

- Power Swing Blocking (PSB)
- Out-of-Step Tripping (OST)
The Strategies

- **Strategy #0**
  Load shedding in the South subsystem

- **Strategy #1**
  Controlled Islanding and load shedding with local measurements

- **Strategy #2**
  Controlled Islanding and load shedding with synchrophasor measurements
Strategy #0

- This is the strategy in operation today;
- The system remains connected in one synchronous island through the 150 kV network;
- A very large amount of load is shed.
Strategy #1

• Islanding scheme (IS) applied to pre-selected network locations, preferably near the electrical center.
• IS performed by installing OST functions in the distance (21) relays of preselected locations;
• Islanding scheme (IS) applied to pre-selected network locations, preferably near the electrical center.

• IS performed by installing OST functions in the distance relays of preselected locations;

• A less amount of load is shed.
Strategy #2

- Controlled Islanding and load shedding with synchrophasor measurements

- Power Swing Detection (PSD) and Predictive Out-Of-Step Tripping (OOST) algorithms patented by Guzman-Casillas and Schweitzer Engineering Laboratories, Inc. (SEL).
• Controlled Islanding and load shedding with synchrophasor measurements.

• Power Swing Detection (PSD) and Predictive Out-Of-Step Tripping (OOST) algorithms patented by Guzman-Casillas and Schweitzer Engineering Laboratories, Inc. (SEL).

• A lesser amount of load is shed.
The Fundamentals of SEL’s Patent

• \((\theta_{\text{Palmar}} - \theta_{\text{Montevideo}}) = \delta\)

• Utilizes:
  • Displacement \(\delta\)
  • Speed \(\dot{\delta}\) or \(S\)
  • Acceleration \(\ddot{\delta}\) or \(A\)

• \(\dot{\delta} \times \ddot{\delta}\) plot
SEL’s Patent – PSD
SEL’s Patent – OOST

V1 (PMU1) → Angle difference calculation → Sufficient voltages Enable → Slip calculation → S

V2 (PMU2) → Angle difference calculation → Sufficient voltages Enable → Slip calculation → S

S → Acceleration calculation → A

A → OOST function

\[ A > K \cdot S + A_{\text{offset}1} \quad \text{OR} \quad A < K \cdot S - A_{\text{offset}2} \]

AND_1

\[ T1 \]

OOST

STABLE

UNSTABLE

A [Hz/s]

S [Hz]

slope \( K < 0 \)

A_{\text{offset}1}

-A_{\text{offset}2}
Quantitative Analysis of Transient Response in the A-S Plane
Simulation Results

• The scenario under study is one with maximum thermal generation with some hydro units in service. The scenario assumes that one of the 500 kV Palmar-Montevideo TL is out of service and a 3-phase fault occurs at the remaining 500 kV line in the Montevideo end.

• The clearance times used were:
  • t=60ms (3 cycles) for the near end
  • t=80ms (4 cycles) for the far end
Simulation Results for Strategy #1

Bus frequency (Hz)

North island

South island

Time (sec)
Simulation Results for Strategy #2
# Load Shedding

<table>
<thead>
<tr>
<th>Strategy #0</th>
<th>Strategy #1</th>
<th>Strategy #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 MVA</td>
<td>500 MVA</td>
<td>420 MVA</td>
</tr>
<tr>
<td>100 %</td>
<td>82 %</td>
<td>70 %</td>
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1/3 of Uruguay total load
• The paper presented two strategies for controlled islanding of the Uruguayan power system: one using only local measurements and the other using synchrophasors.

• Simulation results showed that controlled islanding of the North-South tie with fast load shedding with both strategies performed significantly better than the current utility practice.

• The necessary load shedding was reduced by 18% when the PSB-OST scheme (using only local signals) was utilized, and by 30% when the OOST scheme (using synchrophasor measurements).
Conclusions

• The strategy that uses synchrophasor measurements is more attractive since it is able to curtail less amount of load, due to its predictive capability.

• However, the strategy that uses only local signals should not be discarded since it provides a simple and cost-effective solution to the problem. It also has the advantage that it can be implemented with the current protection system already in place, besides being a backup for the synchrophasor-based OOS protection scheme.
THANK YOU

for your patience and attention