Part 3 - Situational Awareness & Risk Management case study

September 8, 2011
Pacific Southwest Blackout

April 2014 presentation - Lehigh University & IEEE LV Local Chapter Meeting
By Jim Robinson - Relion Associates LLC

September 8, 2011 Event

- 11 minute cascading outage in Pacific Southwest
- 2.7 million customers out in AZ, S.CA, MX (up to 12 hrs.)
- Initiated when single 500 kV line tripped; not sole cause
- Power redistributed, increasing flows, dropping voltages & overloading equipment in underlying systems
- Led to tripping lines, generators, automatic load shedding, and operation of Remedial Action Scheme (RAS) and intertie separation scheme
- Restoration process generally effective
Customer Impacts

<table>
<thead>
<tr>
<th>Entity</th>
<th>Load Lost (MW)</th>
<th>Homes &amp; Businesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDGE</td>
<td>4,293</td>
<td>1.4 million</td>
</tr>
<tr>
<td>CFE</td>
<td>2,150</td>
<td>1.1 million</td>
</tr>
<tr>
<td>IID</td>
<td>929</td>
<td>146 thousand</td>
</tr>
<tr>
<td>APS</td>
<td>389</td>
<td>70 thousand</td>
</tr>
<tr>
<td>WALC</td>
<td>74</td>
<td>Note</td>
</tr>
</tbody>
</table>

Note: 64 MWs of WALC’s load loss affected APS’s customers

Joint FERC/ NERC Inquiry

- Joint Inquiry announced September 9, 2012
- Teams formed comprising over 30 senior technical staff of FERC and NERC, plus several NERC contractors and industry subject matter experts
- Multiple meetings, interviews and exchanges with affected entities to gather facts
- Team products combined into final public report
- Public report is available on the web along with numerous presentations given in 2013
Simplified System Diagram

WECC

Serrano
Devers
Palo Verde

SONGS
Path 44

SDG&E

Miguel

Imperial Valley

CFE

Imperial Irrigation District

WAPA Lower Colorado

Hassayampa

H-NG Corridor

12% of H-NG loss
11% of H-NG loss

77% of H-NG loss

Path 44

Sequence of Events
Phase 1 - Pre-Disturbance

- Hot, shoulder season day; some generation and transmission outages
- High loading on some key facilities: Hass.-N.Gila at 78% of normal rating; C.Valley transformers at 83%
- 15:27:39: APS technician skipped a critical step in isolating the series capacitor bank at North Gila substation; HNG trips
Phase 2 - Trip of H-NG 500 kV

- Hassayampa-N.Gila 500 kV trips at 15:27:39
- SCE-SDGE flow (Path 44) increases by 84%, IID and WALC systems pick up 23% of Hass.-N.Gila flow
- C.Valley 230/92kV #1 & #2 transformers immediately overload above relay settings
- Path 44 at 5,900 amps; 8,000 amp relay limit on SONGS separation scheme

Hass. - N. Gila 500 kV Line Trip

South of SONGS Current

CCM Unit 1 generator trip

Hassayampa – N. Gila 500 kV line trip
Phase 3 – Trip of CV Xfmrs

15:28:16 – C. Valley 230/92kV #1 & #2 trip on overload relays [Ramon 230kV line CBs now open at C. Valley 230kV sub.]

• Very low voltage (< 90%) in WALC 161 kV system

• Loading on Path 44 increases to 6,700 amps
Phase 4 - Ramon Xfmr Trip

15:32:10 – 15:35:40

- 15:32:10 [4 minutes after CV 230/92kV #1&2 trips]
  Ramon 230/92kV transformer trips on overload relay
- Severe low voltage (< 85%) in WALC 161 kV system
- IID 92kV undervoltage load shedding (~10 second delay);
  loss of generation and 92 kV transmission lines
- Loading on Path 44 increases to 7,800 amps; settles at 7,200 amps
Voltage in Northern IID 92 kV System

- Over-Voltage Trip of 92 kV System Capacitors
- Trip of Over 400 MW in Northern IID 92 kV Load Pocket

WALC - Blythe 161 kV Voltage

- Trip of Hassayampa – North Gila 500 kV Line
- El Centro – Pilot Knob 161 kV Line Trip
- Trip of Coachella Valley 230/92 kV Transformers
- Yuca 161/69 kV Transformers 1 and 2 Trip
- Trip of Over 400 MW in Northern IID 92 kV Load Pocket
- Ramon 230/92 kV Transformer Trip
Phase 5 – Yuma AZ Separates

- Yuma AZ separates from IID and WALC when Gila and Yucca transformers trip
- Yuma load pocket isolated on single tie to SDG&E
- Loading on Path 44 increases to 7,400 amps after Gila transformer trip; to 7,800 amps after Yucca transformers and generator trip
Phase 6 – High-Speed Cascade

15:37:55

- **El Centro – Pilot Knob**: 161kV line trips; IID 92 kV system radial from SDG&E via 230kV S-Line
- WALC 161 kV system voltage returns to normal
- Path 44 exceeds 8,000 amp setting and timer starts

15:37:58 – 15:38:02.4

- S-Line RAS trips Imp. Valley generation and 230kv S-Line, isolating IID from SDG&E
- Path 44 loading increases to as high as 9,500 amps and reduces to 8,700 amps after isolating IID
El Centro–Pilot Knob 161kv trip

Imperial Valley – El Centro 230 kV “S” line trip

CLR generating units trip

SONGS separation

El Centro – Pilot Knob 161 kV line trip

Phase 6 – High-Speed Cascade

- SONGS separation scheme operates; forms SDG&E, CFE, Yuma combined island
- Combined island frequency begins to collapse
Phase 7 - Yuma Separates

• Yuma island separates from SDG&E when IV-NG 500 kV trips on underfrequency
• Yuma load pocket begins to collapse
• APS UFLS begins to operate, but insufficient to stabilize Yuma load pocket

UFLS Operations in the Island

15:38:23.12
Phase 7 – CFE Separates

- APS, SDG&E and CFE UFLS continues
- CFE separates from SDG&E

15:38:23.13

Phase 7 – Darkness

- IID, Yuma, SDG&E, and CFE blacked out

By 15:38:38
Key Findings

Weaknesses in two broad areas [Risk Management]:
• Operations planning
• Real-time situational awareness

Contributing factors [Risk Management]:
• Impact of TO sub-100 kV facilities operating in parallel with higher voltage systems
• Failure to recognize local SOLs that are interconnection IROLs
• Not studying/coordinating effects of protection systems and Remedial Action Schemes (RAS) during contingency scenarios

Operations Planning

Failure to consider in seasonal, next-day, and real-time studies:
• Pre-contingency Status of External generation and transmission facilities
• Impact of External single contingencies
• Local transformer overload trip impacts on external systems (local SOLs that are really interconnection IROLs)
• Lack of in-depth joint studies by adjacent TOPs and RC
Operations Planning

Recommended TO, TOP/BA Improvements:

- **Obtain pre-contingency information** from neighboring BA, TOPs/TOs and RC including:
  - transmission outages and schedules, generation outages and schedules, load forecasts, and BA/TOP scheduled interchanges
- Identify and plan for **external** contingencies that could impact their systems and **internal** contingencies *that could impact neighbors’ systems*
- **Coordinate & jointly review planning studies** to ensure operation of affected Rated Paths will not result in reliability problems

Situational Awareness

Recommended Improvements:

- **Expand entities’ external visibility** in models through *more complete data sharing*
- **Improve use of real-time tools** to ensure constant monitoring of potential internal or external contingencies
- **Improve communications** among entities to help maintain situational awareness
- **TO, TOP & RC should review** their real-time monitoring tools (such as State Estimator and RTCA) to **ensure key facilities are correctly represented**
System Protection Issues

Recommendations:
• TOs review transformer overload protection relay settings
• TOPs plan to *take proper pre-contingency mitigation measures* considering emergency ratings and overload protection systems
• All *special protection systems* and separation schemes (RAS, SPS and Safety Nets) *studied and coordinated periodically* to avoid unintended or undesirable effects

Part 1, 2 and 3

- Part 1 – case study US/CA 2003 Blackout
- Part 2 – Scientific industry (STEM) renewed focus on Situational Awareness & *Risk Management* (*3 step process!*)
- Part 3 – case study Pacific SW 2011 Blackout
- Questions? Slides to remember . . .
WALC - Blythe 161 kV Voltage

Slides to remember . . .

- Trip of Hassayampa – North Gila 500 kV Line
- El Centro – Pilot Knob 161 kV Line Trip
- Trip of Coachella Valley 230/92 kV Transformers
- Yucca 161/69 kV Transformers 1 and 2 Trip
- Trip of Over 400 MW in Northern IID 92 kV Load Pocket

Phase 4 - Ramon Xfmr Trip

Slides to remember . . .

- 15:32:10 [4 minutes after CV 230/92kV #1&2 trips] Ramon 230/92kV transformer trips on overload relay
- Severe low voltage (< 85%) in WALC 161 kV system
- 15:32:13 – 15 Blythe-Niland and Niland – C.Valley 161kV lines trip
- IID 92kV undervoltage load shedding (~10 second delay); loss of generation and 92 kV transmission lines
- Loading on Path 44 increases to 7,800 amps; settles at 7,200 amps
Slides to remember... “Trees”

\[ G = \text{Max Sag Ground Clearance – Determined from Line Plan & Profile} \]

WSZ = Wire Security Zone (Table 1)

A = Additional Clearance to allow for Growth of Vegetation

Slides to remember... “Tools & Training”

Situational Awareness & Human Communication Training, Command & Control Tools (TOP alarms fail 2:14PM)
Keynote speaker – Dave Nevius

Risk Management – Jim Robinson

1. Failure Modes (identification & likelihood)
2. Consequences (of each Failure Mode)
3. Costs (to improve step 1 or 2, or both)

Professional Scientist (STEM) are key in performing Risk Management evaluations

Any Questions ??