Post-Facto Analysis of a Near-Blackout Event[1]

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ABSTRACT

On August 22nd, 2002, Panamá's electrical grid experienced a major disturbance that started with a phase-to-ground short-circuit and brought the system near voltage collapse. Neither significant frequency excursions nor transient phenomena took place, but the voltage profile fell to critical levels. This paper reviews the system's behavior during the disturbance and summarizes the results of the steady-state stability evaluation of the system conditions prior and during the event. The data used for reconstructing the events were retrieved from the National Dispatching Center (CND) Historical Information System (HIS). The analysis was conducted with the real-time version of QuickStab® that is currently running on the company's Ranger SCADA/EMS platform.

SEQUENCE OF EVENTS

Bulk Transmission Grid Overview

Panamá's bulk transmission network is longitudinal and encompasses seven substations on the high voltage side of the grid (230 KV). The maximum demand is approximately 836 MW. The load is concentrated mostly in Panamá City, with approximately 47% of it, i.e., 390 MW, being supplied by generators situated IN the west side of the country at about 247 miles away from the city.

Reactive compensation is provided by three reactor banks and four capacitor banks. The reactors are strategically located in the central and west regions in order to prevent over voltages during low demand periods. The capacitors are used to raise the voltage during the maximum demand period and are located in the substation Panamá near the load center.

Chronology

15:14:37.560 hours

After a lightning strike on the PANAMA II - Bayano transmission line (Figure 1.a), the phase C conductor remains hanged on a metallic pole, which turns the fault into a permanent short-circuit. Line protections work correctly and open the line at both ends. Due to the rapidly changing readings, the state estimator's execution is suspended.

15:15:00 hours

Twenty-three seconds later, the COPESA generators trip also (Figure 1.b). The frequency drops to 59.79 Hz and the voltage reaches 211 KV.

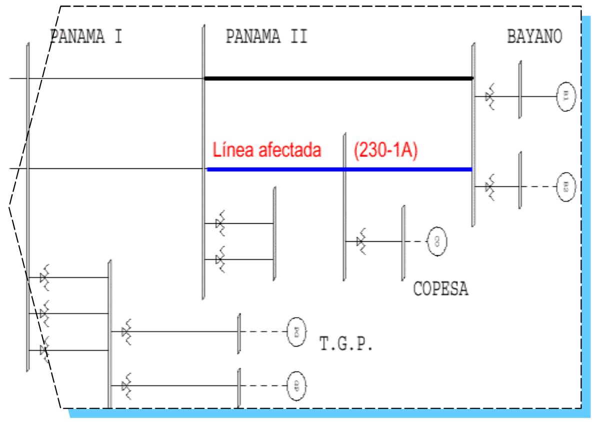

Figure 1.a Line affected by lightning

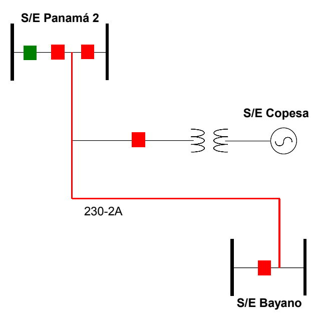

Figure 1.b COPESA generator trips

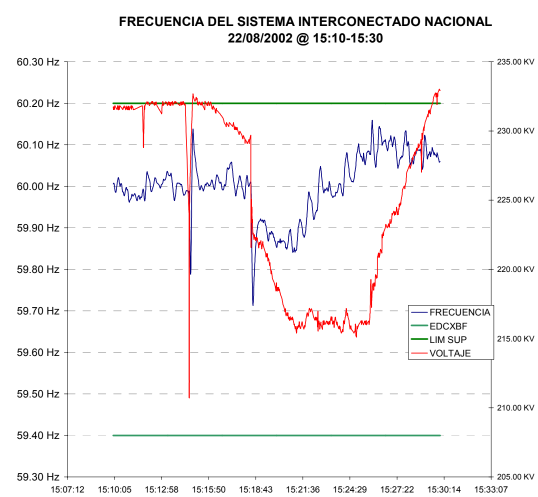

Figure 2 Frequency excursions during the event

The primary regulation responds immediately and the system's frequency goes back to normal (Figure 2).

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15:18:43 hours

Approximately three minutes later the three generators from PANAM power plant trip and the frequency and voltage drop to 59.71 Hz and 216 kV, respectively.

The reduction of reactive supply is severe. Prior to tripping, each unit was generating approximately 6.36 MVArs for a total of 19.09 MVArs. Considering the 8.43 MVArs lost from COPESA, the reactive power deficit now amounts to 27.52 MVArs. As a result, the system can't meet the reactive demand from the distribution network and the voltage profile remains low.

15:21 to 15:25 hours

Since no generators are available to supply reactive power to the load center, the distribution companies are alerted of the situation and the system operator asks them to shed approximately 20 MW each. As shown in Figure 2, the load reduction helped the frequency but didn't solve the voltage problem. Therefore, the system operator asked for additional load shedding but the distribution companies did not honor the request.

15:26 – 15:27 hours

The three PANAM generating units that had tripped at 15:18:43 hours come back on line.

15:30 hours

Voltage profile starts to improve due to the reactive power supplied by the PANAM generators.

ANALYSIS

The CND engineering group in charge of system security analyzed this event by using historical data from HIS. Since the state-estimator was suspended during the event and couldn't converge in study mode with snapshot data either, the last successful run before the event was taken as reference (Case 1).

Two additional load-flows (Cases 2 and 3) were calculated with data taken from the real-time snapshots stored in HIS. These cases were then analyzed with QuickStab®.

Steady-state stability conditions before event

Case 1 shows that the Panamanian grid was operating within acceptable security margins (Figure 3a). The generating units were up and running as scheduled. The total reactive demand was 229.49 MVArs and the voltage levels were acceptable. The P-V curve shown in Figure 3.b suggests that the system was far from instability.

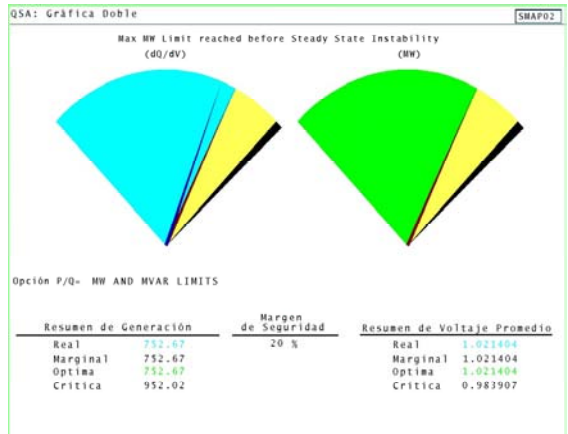

Figure 3.a

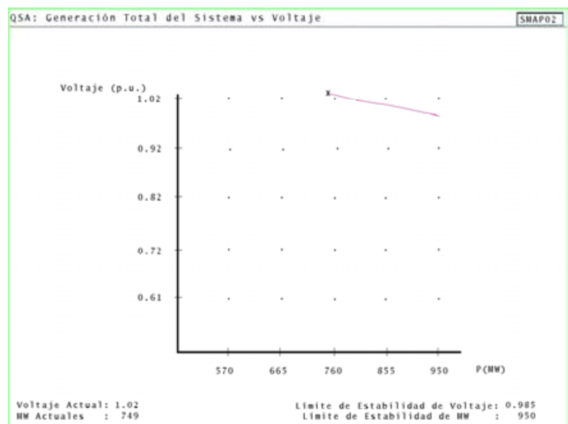

Figure 3.b

Figure 4

Steady-state stability conditions after tripping of COPESA generation

Case 2 was built from data retrieved immediately after the tripping of the line 230-2A and the loss of COPESA generation. The distance to steady-state instability is depicted in Figure 4 (curve P-V not shown).

At that time, the network was relatively close to the security margin but the disturbance was in progress and the transmission grid was entering the "alert" zone (shown on the speedometer chart with yellow color).

It's important to note, however, that although the stability reserve (distance to instability) was acceptable, the operating point was slowly moving towards instability, i.e., the system's critical state (shown in red). Note, also, that the total reactive demand had increased to 237.5 MVArs.

Getting closer to steady-state instability (Case 3)

In the third and last case of our analysis, the two PANAM units that had actually tripped during the event were outaged from the base case. As clearly shown in Figure 5.a, this caused the system to quickly approach the steady-state stability limit. The total reactive demand increased to 250.65 MVArs.

These results are fully consistent with the real-time readings shown in the event's chronology, where the loss of the third PANAM unit caused the voltage profile to reach near-critical values.

Conclusions

The 22nd August 2002 event brought the Panamanian high voltage transmission grid to near-blackout conditions due to the loss of generation (and reactive injections) in a power plant (PANAM) situated near the load center.

The post-facto steady-state stability analysis was performed with the real-time version of QuickStab® by using historical data.

The assessment indicated that the lack of reactive power reserve, given the ready MW reserve condition after the loss of the three units from PANAM generating plant, pushed the system into an unsafe region near the state of voltage collapse. The analysis also showed that the system's behavior, documented by the real-time measurements stored in HIS, was reliably predicted by QuickStab®.

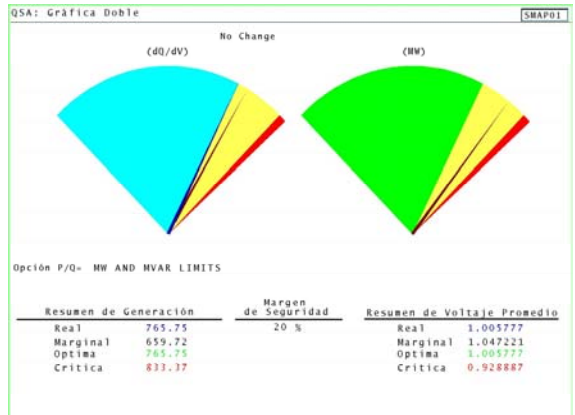

Figure 5.a

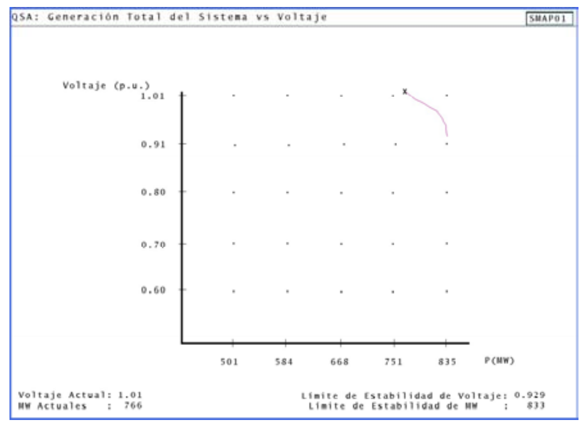

Figure 5.b

About the author

Luis A. Gonzalez L. is an experienced power system engineer with extensive background in planning, operations and control. His experience also encompasses database management and software development tools for engineering and Internet applications. He is employed by the Panamanian System Operator in the National Dispatching Center of ETESA. Mr. Gonzalez' current responsibilities focus on SCADA/EMS applications with particular emphasis on real-time and off-line security applications.

<u>Notes</u>

All the pictures shown in this paper were taken directly from CND's SCADA/EMS displays
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