Brazilian Blackout 2009

Blackout Watch

Brazil benefited from correct performance of islanding schemes.

On November 10th, 2009, at 10:13 PM, Brazilian National Interconnected System (NIPS) was submitted to a significant disturbance that caused the interruption of 40% of its load. The disturbance was triggered by the automatic disconnection of 765 kV transmission line (TL) Itaberá-Ivaiporã #1, #2 and #3 under adverse weather conditions. The loss of the three circuits imposed 5,564 MW generation rejection at Itaipu 60 Hz Hydro Plant, as well as tripping of the remaining 525 kV, 500 kV, 230 kV and 138 kV circuits of South-Southeast Interconnection, rejecting 2,950 MW additional power flow from South to Southeast, and the tripping of the HVDC link (two ± 600 kV bi-parallel with the three circuit 765 kV TL) which were loaded with 5,329 MW. This were followed by other disconnections, leading to a total load interruption of 24,436 MW (40%) along NIPS, distributed as listed below:

- Northeastern Region: 802 MW
- Northern Region (Acre and Rondônia States): 195 MW

NIPS operating conditions right before the disturbance are summarized in Figure 1. This summary will be easier to understand with the aid of NIPS map presented on Figure 9 of the paper “Wide Area Protection Systems in Brazil” in 2009 PAC World Autumn Issue.

The disturbance was started by a phase B to ground fault on 765 kV TL Itaberá-Ivaiporã #1 inside Itaberá Substation (t0). At t0+13.5ms, with the first fault still present, another single phase to ground occurred, this time involving phase C of 765 kV TL Itaberá-Ivaiporã #2. In a sequence, at t0+17ms, still with the two precedent faults present, a third single phase to ground occurred on phase A of Itaberá 765 kV busbar, section A (double bus with breaker and a half arrangement).

So, the faults occurred almost simultaneously inside TL 765 kV Itaberá-Ivaiporã #1 and #2 and section A of Itaberá 765 kV busbar, and remained present for a few moments, imposing to NIPS a three phase to ground fault at Itaberá Substation up to when the individual short-circuits were cleared by automatic tripping of the faulted components.

The fault on 765 kV TL Itaberá-Ivaiporã #1 was cleared at both terminals by the operation of main 1 and main 2 protections, which are based on the travelling wave principle. The fault on 765 kV TL Itaberá-Ivaiporã #2 was cleared at both terminals by the operation of directional overcurrent functions associated to teleprotection schemes. The fault on section A of Itaberá 765 kV busbar was cleared by differential protection operation. Instants after the clearing of this last fault, the instantaneous residual overcurrent protection of the shunt reactor directly connected (by switch – no breaker) to Ivaiporã terminal of 765 kV TL Itaberá-Ivaiporã #3, leading to the disconnection of this transmission line, thus interrupting totally the connection between Itaberá and Ivaiporã Substations.

At Itaipu 60 Hz Hydro Plant, five of nine generating units were tripped (the tenth unit was out of service), rejecting 3,100 MW of generation by operation of the 765 kV Trunk Wide Area Protection Scheme (WAPS), due to the triple contingency between Itaberá and Ivaiporã Substations, thus promoting islanding and preservation of the Southern Subsystem. As a consequence, 500 kV TL Bateias-Ibiúna #1 e #2 were tripped because of overload and power swing between Southern and Southeastern Subsystems, with a frequency increase up to 63.5 Hz in Southern Subsystem and a frequency decrease down to 58.3 Hz in Southeastern Subsystem.
Paraguayan Power System are under analysis by Operation The performance of the SPS and its consequences for the what imposed a significant overfrequency and the subsequent System remained in parallel with nine Itaipu generating units, Electric System did not occur. So the Paraguayan Power Itaipu 50 Hz Hydro Plant generating units with Paraguayan by islanding two Itaipu generating units and the Paraguayan very high overfrequencies in the Paraguayan Power System, its ten generating units. In case of full load rejection there is a NIPS. Itaipu 50 Hz Power Plant was operating with nine of 5,329 MW, thus isolating Itaipu 50 Hz Hydro Plant from permanent DC undervoltage protection, interrupting a flow of almost the total load in Southern Subsystem, the whole #3 were tripped by 765 kV trunk WAPS, isolating Itaipu #1 e #2 disconnections 50 Hz Hydro Plant, which was, until then, connected to the Southeastern System. By the same reasons here depicted, the transmission lines that interconnect Mato Grosso do Sul State System with Southern and Southeastern Subsystems were also tripped by their protections, leading this state electric energy supply to collapse.

With the above mentioned disconnections, there was a voltage collapse in the Southeastern Subsystem, especially in São Paulo, disconnecting the HVDC link by operation of permanent DC undervoltage protection, interrupting a flow of 5,329 MW, thus isolating Itaipu 50 Hz Hydro Plant from NIPS. Itaipu 50 Hz Power Plant was operating with nine of its ten generating units. In case of full load rejection there is a Special Protection Scheme (SPS) to prevent the occurrence of very high overfrequencies in the Paraguayan Power System, by islanding two Itaipu generating units and the Paraguayan Power System.

Those circumstances took place, as described above, but the SPS did not operate and the automatic islanding of two #1 and #2 disconnections Itaipu 50 Hz Hydro Plant generating units with Paraguayan Electric System did not occur. So the Paraguayan Power System remained in parallel with nine Itaipu generating units, what imposed a significant overfrequency and the subsequent tripping of the 220 kV interconnecting transmission lines. The performance of the SPS and its consequences for the Paraguayan Power System are under analysis by Operation Brazil-Paraguay Commission. The disturbance caused collapse in Rio de Janeiro, São Paulo, Espírito Santo and Mato Grosso do Sul states and thus load shedding by ERAC (regional distributed underfrequency load shedding scheme), affecting loads in Northeastern Subsystem and Minas Gerais, Goiás, Mato Grosso, Acre and Rondônia states, these last two states after their separation from Southeastern/Center-West Subsystem.

It is important to note that the disturbance that caused this blackout was way more severe than the disturbances that caused 1999 and 2002 blackouts, not only because of involving three phase to ground short-circuit, but also for causing the disconnection of the 765 kV Transmission Trunk. Still, comparatively, the consequences of this event for NIPS were less severe, as one can ascertain by the preservation of almost the total load in Southern Subsystem, the whole load preservation at the National Capital, Brasilia (DF) and by the small amount of load loss in Minas Gerais, Goiás and Mato Grosso states. In Northeastern Subsystem, the loss of load was restricted to the amount shed by ERAC’s operation and the average restoring time was 20 minutes. It is noteworthy that NIPS fundamentally benefitted of its islanding schemes proper performance and of its transmission system enhancement, mainly those involving reinforcement of interconnections between subsystems.

The average NIPS load restoration time was 222 minutes. Such a long time was caused by unsuccessful black-start of hydro plants within the restoration corridors, as well as by some telecommunication failures. Both problems are already addressed and will be solved in a short term horizon.

Based on the available data, the severity of the disturbance was estimated in 90 system.minutes, according to international methodology of calculation. This is lower than 1999 and 2002 blackouts, which had severities of 111 and 106 system.minutes, respectively.