Requirements in Design and Implementation of Restoration Facilities and Procedure in Order to Improve Power System Restoration: The Brazilian Experience

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Objectives

This paper presents in detail the improvements incorporated to the restoration process, in all of its phases, by the National Operator of the Electric System – ONS (Brazilian ISO), the restoration times verified in the National Interconnected Electric System (NIS) and the goals pursued for the reduction of those times, to be achieved in the future.

This paper also presents some improvements in the restoration processes of the São Paulo Area of the NIS.
Operative Security Actions in the NIS

- **Preventive actions:** to minimize the probability of occurrence of large disturbances;

- **Corrective actions:** to minimize the spreading of unavoidable disturbances through the system;

- **Optimized restoration actions:** to reduce the restoration time to acceptable values.

- **Disturbances analysis:** Identify eventual problems to avoid the occurrence of new blackouts or minimizing their consequences.
**The NIS Defense Plan**

- **Disturbances analysis:** Identify eventual problems to avoid the occurrence of new blackouts or minimizing their consequences.
Restoration Stages

Fluent

- started by high reliability (black start) hydro-power units
  - the startup voltage level and the minimum amount of generators must be established for each process;
  - the priority load pick up is pre-defined;
  - The geo-electrical areas are first restored in a practically independent manner during the fluent phase
- the maximum amount of power in each priority load pick up for each geo-electrical area must be pre-defined
  - it should consider extreme load configurations to insure that the restoration process can be carried out at any time.
Restoration Stages

Coordinated

- The National and Regional Operating Centers coordinate the load shedding and closing of loops or parallel in distinct geo-electrical areas.
  - The restoration can also be coordinated when there is any sort of impediment that requires the action of a group of distinct operating centers or a higher hierarchical entity.
  - The utilities are responsible for the cold load pick up within pre-defined parameters.
  - There are restoration procedures that involve in the beginning only fluent process and later on start the coordinated one, while the restoration can be purely in a coordinated manner.
The present restoration process implemented in the Brazilian Grid includes 34 fluent restoration areas, defined by region (North: 3 areas; Northeast: 6; Southeast: 16; South: 9)
Actions to Reduce Restoration Time

✦ Improvements in off-line studies, by upgrading criteria, databases, software’s (new features, friendly interfaces);

✦ Elaboration of more detailed and precise operation instructions;

✦ Identification of new resources for the energization procedure;

✦ Operators training;

✦ Feedback from disturbances analysis.
Improvements in Off Line Studies

- Grid Code was updated with participation of all involved agents, resulting in the establishment of new criteria / procedures and responsibilities.

- ONS in association with CEPEL (Research Center) and Universities (UFJF and UFRJ) developed the project “Improvements in Computational Tools to Speed up Restoration Studies”.

Elaboration of More Detailed and Precise Operation Instructions

Studies are done with close and intense participation of real-time staff, taking into account their knowledge on the existing problems/constraints, as well as on the feasibility of certain maneuvers.

The effective participation of real-time staff will avoid operational arrangements substations mistakes and will permit the elaboration of more detailed and precise instructions.
Identification of New Resources for the Energization Procedure

- Studies are permanently being developed to evaluate the need for the installation of new reactor units to speed up the restoration process;

- Studies are realized to assess the need for implementing integral black start power plants:
  - For plants belonging to the existing fluent restoration corridors in the NIS;
  - For plants not belonging to the existing fluent restoration corridors → New fluent restoration areas must be created or these plants must be incorporated to the existing corridors defined by the Operator.
As to training of the operation personnel, the following steps are proceeded:

- Presentation of the off-line studies;
- Technical support for the elaboration/revision of the operation instructions;
- Operators training, consisting of: simulation on computers and drills on the real system.
Feedback From Disturbances Analysis

From disturbances analysis activity, adopted in the Brazilian National Interconnected Electric System (NIS), it is possible to identify eventual problems, analyze them and propose measures to avoid the occurrence of new blackouts or minimizing their consequences.

This activity almost permits the identification of possible improvements in the restoration procedures.
EXEMPLES OF BRAZILIAN POWER SYSTEM RESTORATION

Fluent Restoration of the São Paulo State by 440 kV Transmission System

Coordinated Restoration of the São Paulo State by Itaipu 60 Hz Power Plant and 765 kV and South Systems
Fluent Restoration of Água Vermelha, Ilha Solteira and Jupiá Areas at São Paulo

120 MW
AGV

180 MW
RPR
130 MW

100 MW
SBO

180 Mvar
(AR-1)

4 MQ

6 MQ

180 Mvar
(AR-3)

180 Mvar
(AR-1)

150 MW

BAU

90 Mvar
(AR-1)

SAA

100 MW

150 MW

180 Mvar
(AR-6)

180 Mvar
(AR-2)

250 MW

220 MW

250 MW

180 MW

Tijuco Preto

T. Leste

Ramon

160 MW

130 MW

100 MW

60 Mvar
(RE-1)

60 Mvar
(RE-1)

60 Mvar
(RE-1)

60 Mvar
(RE-1)

60 Mvar
(RE-1)

60 Mvar
(RE-1)

30 MW

Terminal Sul

ETT Centro

Anhanguera

Edgard Souza

Itapetí
Coordinated Restoration at São Paulo Area

AGV 120 MW

130 MW

AR ARA

200 MW

SAA

240 MW

MOM-III

55 MW

BAU

120 MW

TRI

JUP

150 MW

9 MQ

150 MW

OES

110 MW

EMG

150 MW

SBO

100 MW

SUR

100 MW

BOJ

70 MW

TAU

70 MW

Itapeti

Tijuco

Preto

T. Leste

150 MW

Ramon

160 MW

Edgard Souza

Anhangüera

ETR Centro

ETT Centro

250 MW

ETT Pirituba

200 MW

ETI Interlagos

ETR Xavantes

ETT Milton

Fornasaro

100 MW

Terminal Sul

100 MW

ETT Centro

200 MW

Baixada

Santista

Área SE-06

Ibiuna

SUR

70 MW

BOJ

120 MW

10 MQ

6 MQ

4 MQ

06
Older Coordinated Alternative Procedure to Attend Additional Loads at São Paulo State

Paralleling Areas: with Ilha Solteira Area and Henry Borden Area and/or Jupia Area

Additional Loads
Leste 88kV
Ramon 88kV
New Coordinated Restoration of the São Paulo State by Itaipu 60 Hz Power Plant and 765 kV and South Systems Area

Paralleling Areas: with Henry Borden Area and/or Jupiá Area

GNB Area
Load = 1215 MW + 410 MW

SSA Area
Load = 450 MW + 310 MW

Paralleling Areas: with Ilha Solteira Area

ITAIPU 60
ITAIPU 60
FOZ 60
FOZ 60
IVAIPORÃ 765
ITABERÁ
TIJUCO PRETO
BAIXADA
IBIUNA
LESTE
RAMON
TAUBATÉ

4 UG

IVAIPORÃ E.SUL
IVAIPORÃ FURNAS
LONDRINA

330 Mvar
330 Mvar
330 Mvar
330 Mvar
330 Mvar
330 Mvar

360 Mvar
210 MW

320 MW + 60 MW
200 MW
175 MW
Additional Loads Re-established at São Paulo After Parallel Closing Between the 60 Hz Itaipu, 765 kV and South Systems Area and Ilha Solteira Area

**Additional Loads**
- **Leste 88kV:** 420MW
- **Ramon 88kV:** +100MW
- **Taubaté 138kV:** 175MW
Additional Loads at São Paulo After Parallel Closing Between Ilha Solteira Area and the 60 Hz Itaipu, 765 kV and South Systems Area

- **Additional Loads**
  - Leste 88kV: + 100MW
  - Ramon 88kV: + 100MW

- **Areas**
  - **Área GNB**
    - Carga = 1215 MW
    - Até + 410 MW
  - **Área SSA**
    - Carga = 450 MW
    - Até + 310 MW

- **Loads**
  - IBIUNA: 320 MW + 60 MW
  - RAMON: 200 MW
  - ITAPETI: 175MW
  - LONDRINA: 210MW
  - ILHA SOLTEIRA: 6 UG, 180Mvar, 150 MW
  - S. ANGELO: 180Mvar
  - ITABERÁ: 330Mvar
  - IVAIPORÁ 765: 330Mvar
  - IVAIPORÁ E.SUL: 330Mvar
  - IVAIPORÁ FURNAS: 330Mvar
  - FOZ 60: 330Mvar
  - FOZ 60: 150Mvar
  - ITAIPU 60: 360 Mvar

- **Systems**
  - ITABERÁ: 330Mvar
  - ITAIPU 60: 4 UG
  - FOZ 60: 6 UG

- **Networks**
  - Leste 88kV: + 100MW
  - Ramon 88kV: + 100MW

- **Generating Units**
  - IVAIPORÁ: 330 Mvar
  - ITABERÁ: 330 Mvar
  - LONDRINA: 330 Mvar
  - ITAIPU 60: 330 Mvar
Conclusions and Recommendations

Goals of the project “Improvements in Computational Tools to Speed up Restoration Studies”:

- The new features and friendly interfaces implemented in tools allow a more complete analysis resulting in the speed-up of the whole restoration process;

- Significant reduction effort was noticed in the execution and analyses of power flow restoration studies with the possibility to test multiple alternatives, such as in case of unavailable equipments during the restoration corridor;

- Reduction of time of power flow analysis: at the first time when the restoration processes is being determined a little profit of 10 to 15% is noticed, but in case of post-processing the profit goes up more than 50%.
Conclusions and Recommendations

- The disturbances analysis that have occurred in the last years in the Brazilian System have showed that it's worth to invest in the restoration process.

- The time associated to load restoration has decreased. This is very important to the electric system due to its influences in the consumers’ opinion.

- The investment is small compared to the results encountered.

- Now we are analyzing new procedures such as:
  - Reviewing the speed governor sets of some generator unit of the power plants in order to make possible their utilizations in new fluent restoration corridors. This is based on the fact that the speed govern influences the behavior during the load restoration a rejection in the restoration process;
  - The use of static compensator in restoration processes, in the fluent phase.