Remedial Action Scheme Based on Synchrophasor Measurements & System Angle Difference for Peru's 500 kV Grid

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Topics

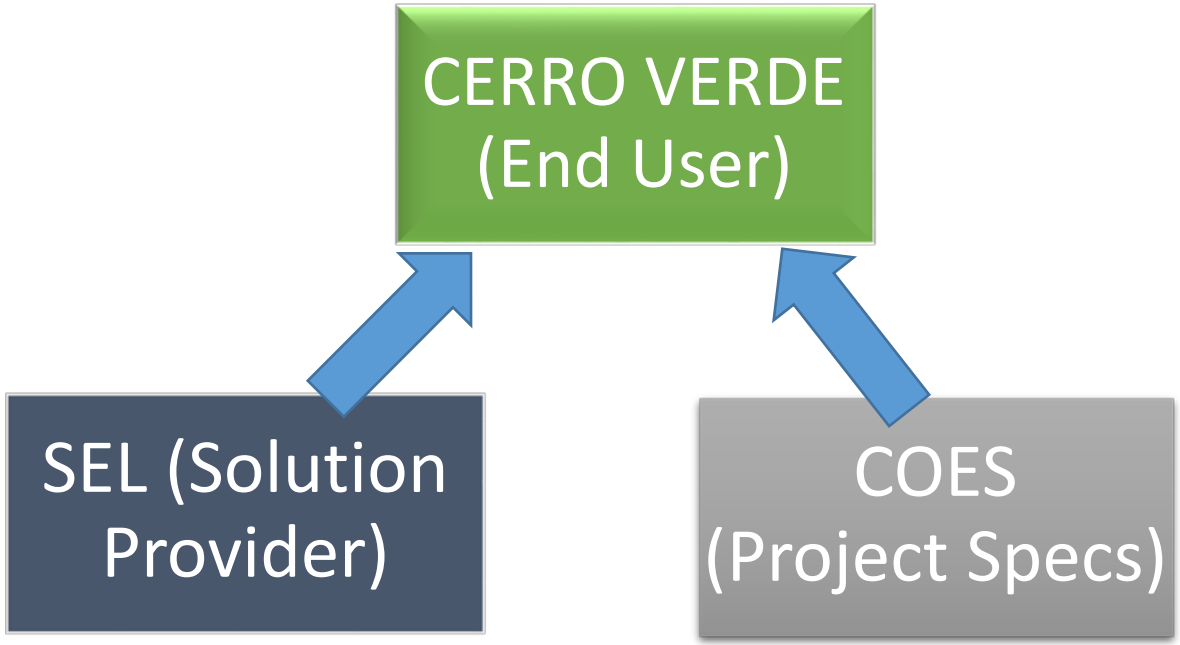
- Overview
- Responsabilities
- Project Scope
- Technical Solution
- Open Discussion

Peru Facts

- Area: 1’285,216 sq km
- Population: 30,814,175
- Local Currency: Nuevo Sol (PEN)
- Stable government for the last 10 years
- Next presidential election in 2016

Cerro Verde

Organization of Project



COES (Comité de Operación Económica del Sistema)

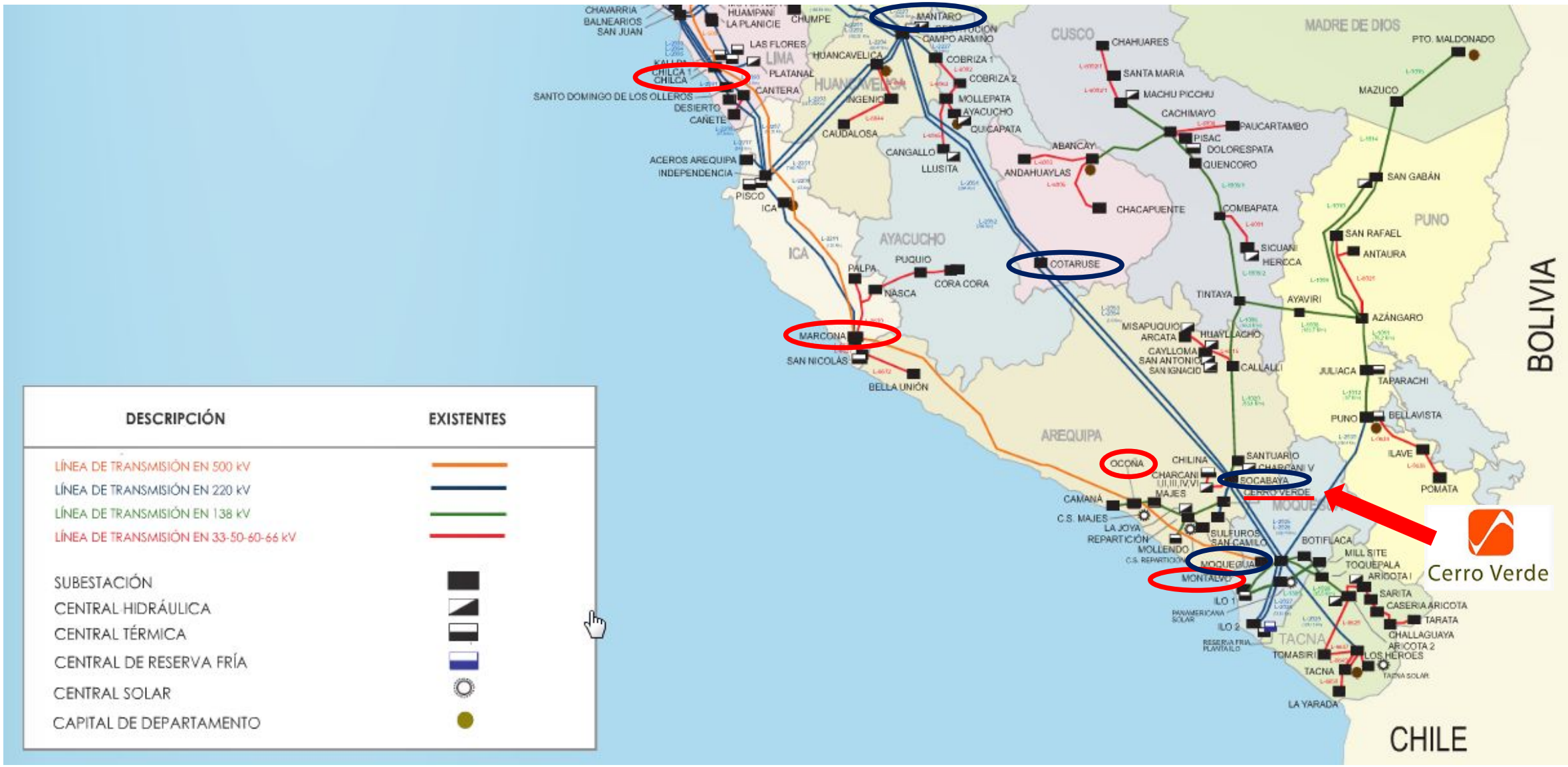
- COES is a non-profit & private entity. Makes decisions to coordinate secure operation of the energy resources and plan growth of transmission system. All power companies are mandated to follow COES's decisions in Perú.
- Information Sistems of COES (SICOES) has 5 sub-systems:
  - •Sistema de Gestión Operativa del COES (SGOCOES)
  - •SCADA / EMS
  - •Sistema de Gestión Documentaria del COES (SGDOC)
  - •WEB-COES / Extranet / Intranet
  - •Transcoes (cálculo de las valorizaciones de transferencias de energía mensuales)

The Ministry of Energy and Mines of Peru and Abengoa Transmisión Sur (ATS), signed a 30-year contract in July of 2010 for the design, financing, construction, operation and maintenance of the 500 KV transmission line that connects Chilca, Marcona, Ocoña, and Montalvo substations (872 kilometers)

Cerro Verde Facts

- Cerro Verde is an open-pit copper and molybdenum mining complex.
- 20 miles southwest of Arequipa, Peru
- Projected for expansion of the concentrator facilities to 360,000 metric tons-per-day (mtd) and provide incremental annual production of approximately 600M pounds of copper and 15M pounds of molybdenum beginning in 2016.
- **Ownership:** 53.56% FCX (**Freeport-McMoRan Inc)**; 21% SMM Cerro Verde Netherlands B.V. (a subsidiary of Sumitomo Metal Mining Company Ltd.); 19.58% Compañia de Minas Buenaventura S.A.A.

Electrical Map of PERÚ



Background

- The 220 kV transmission line between Mantaro – Cotaruse – Socabaya connects generation from the north to the loads in the south.
- The 500 kV line between Chilca – Poroma – Ocoña – Montalvo prevent the system to collapse after the disconnection of the 220kV link to the southern part of the country.
- There are many major mining projects in southern Peru such as: Cerro Verde expansion, Constancia Mine, Las Bambas Mine, & Antapaccay Mine.
- High-Speed Load Shedding is required in the southern Mines before disconnecting the 220kV or 500 kV lines in order to prevent a collapse caused by power oscillations between North-Central areas and the South of Peru.

Defined Solution

- Implement a Remedial Action Scheme (RAS) that, based on the measurement of angles at different points of the 500 kV line, acts on feeders assigned to the ERACMF (Esquema de Rechazo Automático de Carga por Mínima Frecuencia or Under Frequency Automatic Load Shedding Scheme) before power oscillations occur.

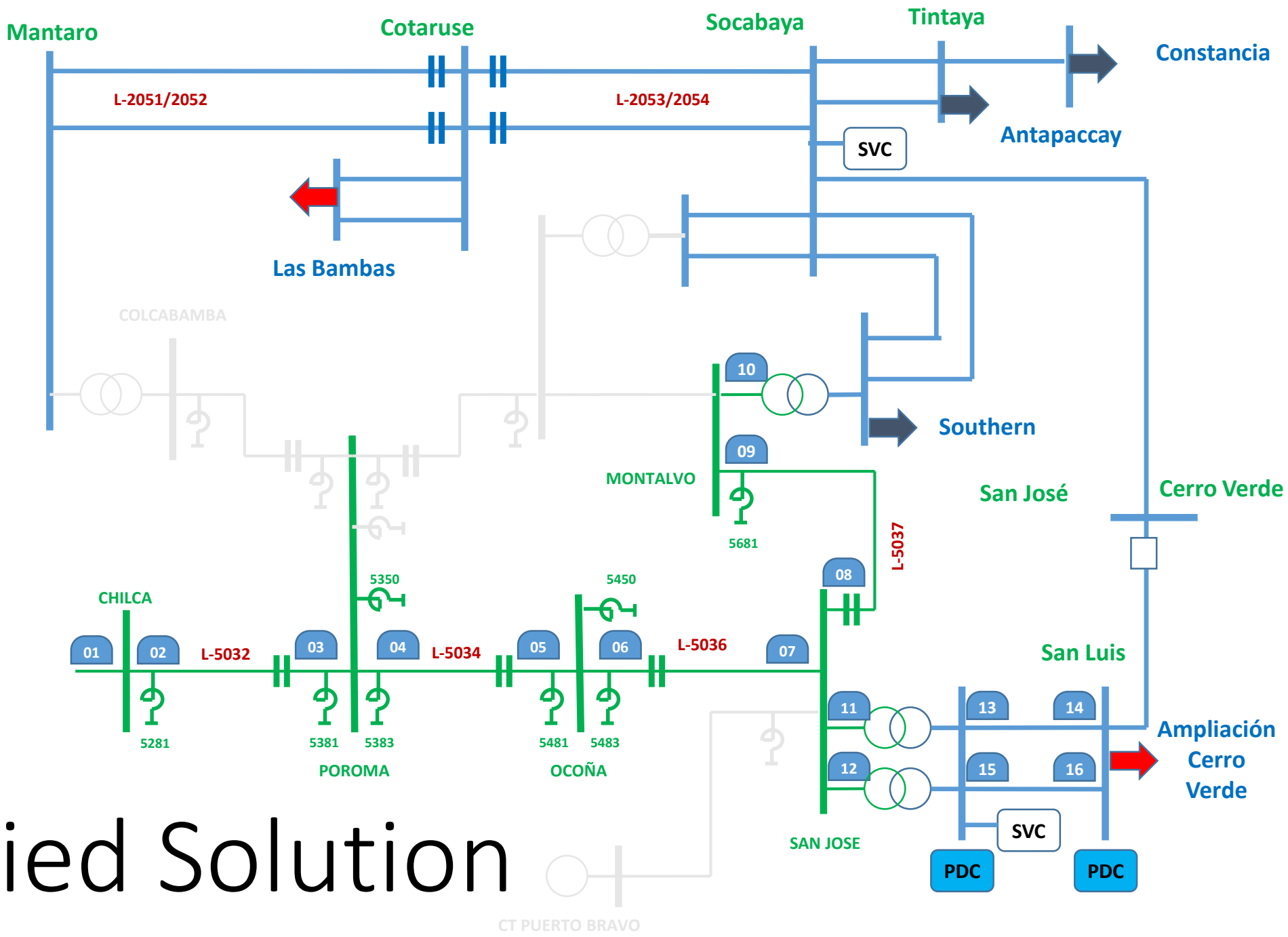
- Implement a control scheme to trip the reactors in 500 kV line, giving priority to disconnect bus bar reactors.

- Future implementation of the RAS scheme in new mining projects entering the SEIN (National Interconnected System) of Peru.

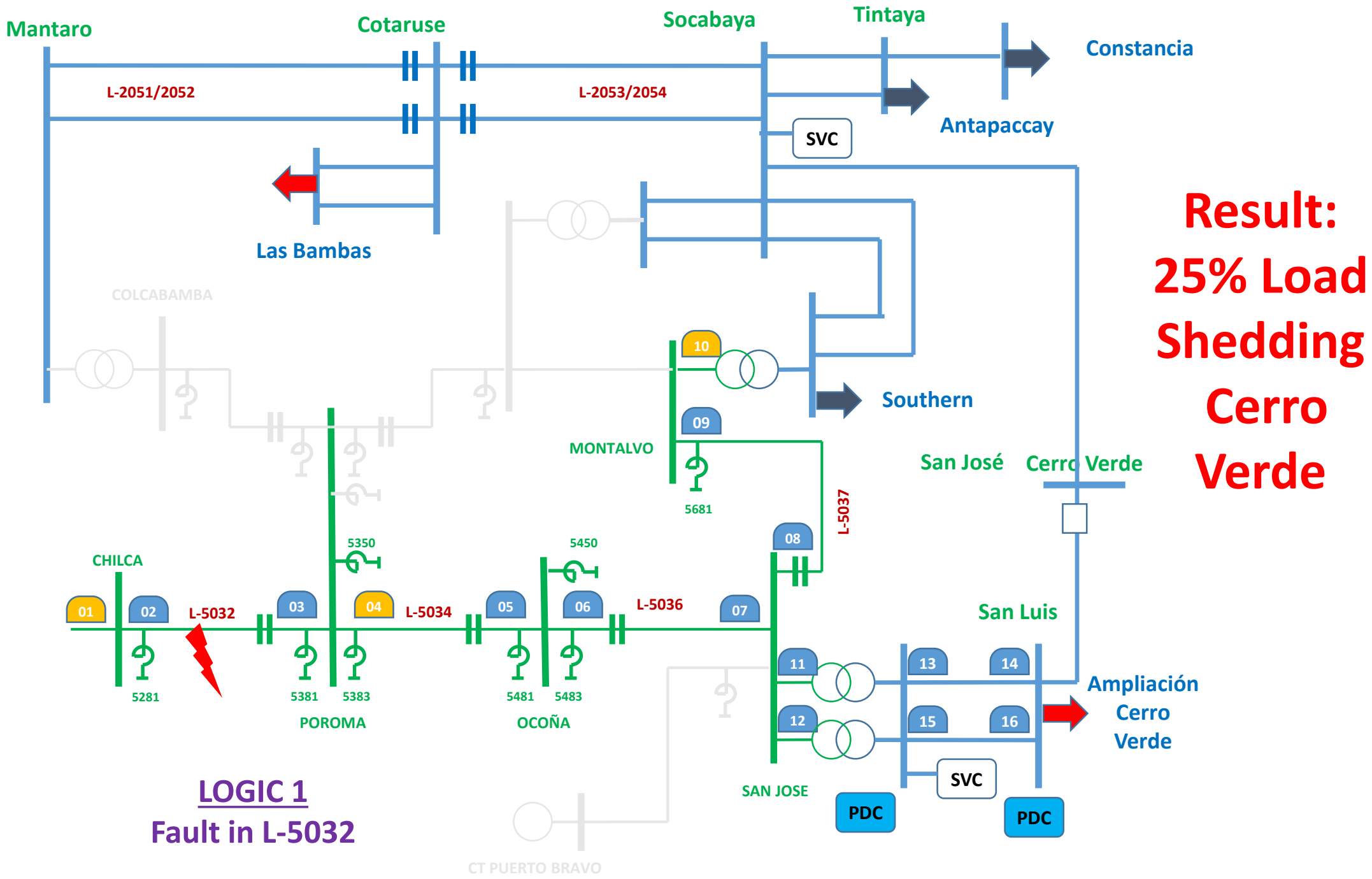
- Logics applied to the RAS are defined as DACA

Project Scope
Synchrophasor RAS System

- System Design
- Panel Manufacturing
- Factory Testing
- Panel Onsite Installation
- System Commissioning
- Training
- Local Support (Local)

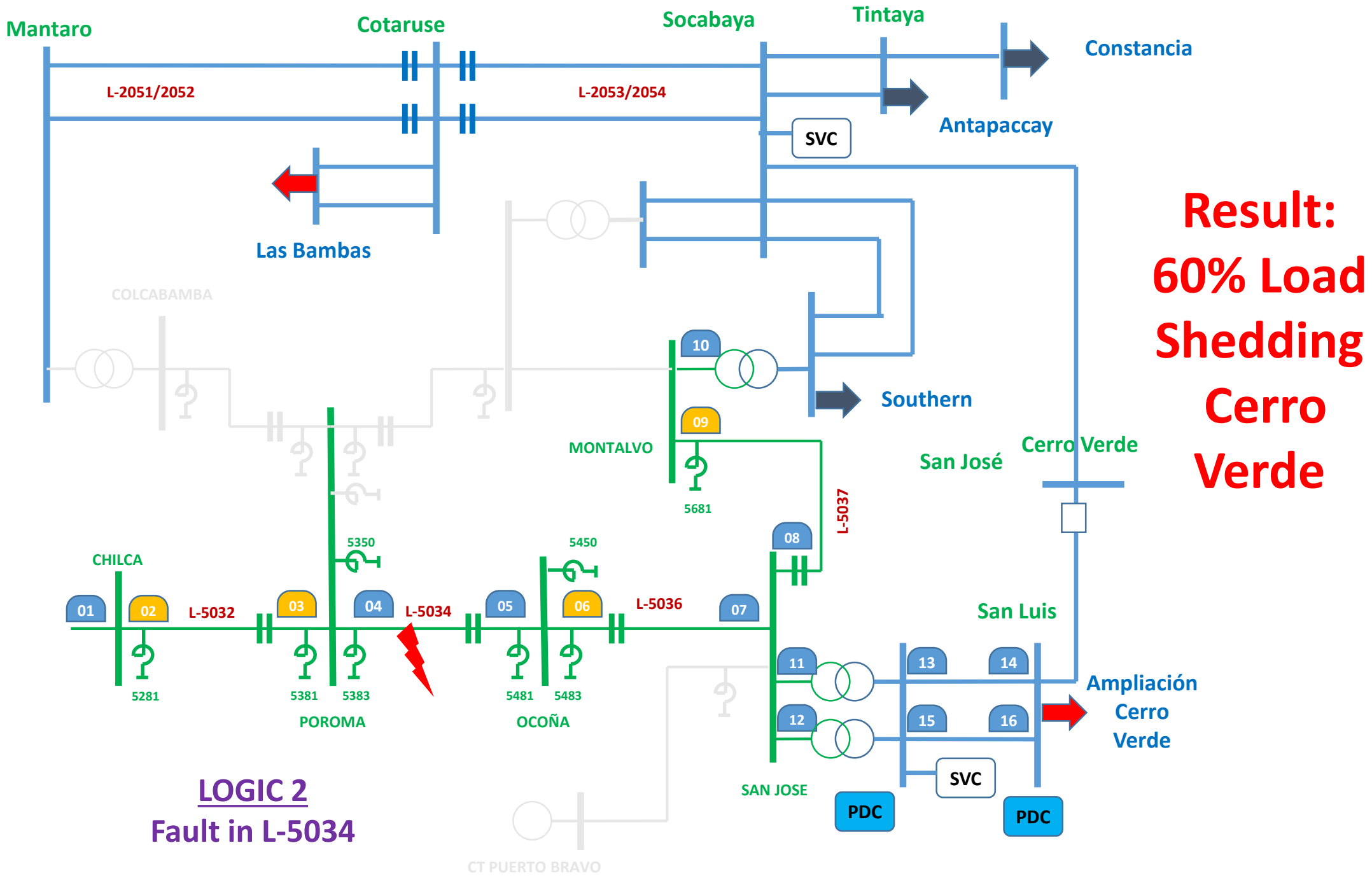


Applied Solution



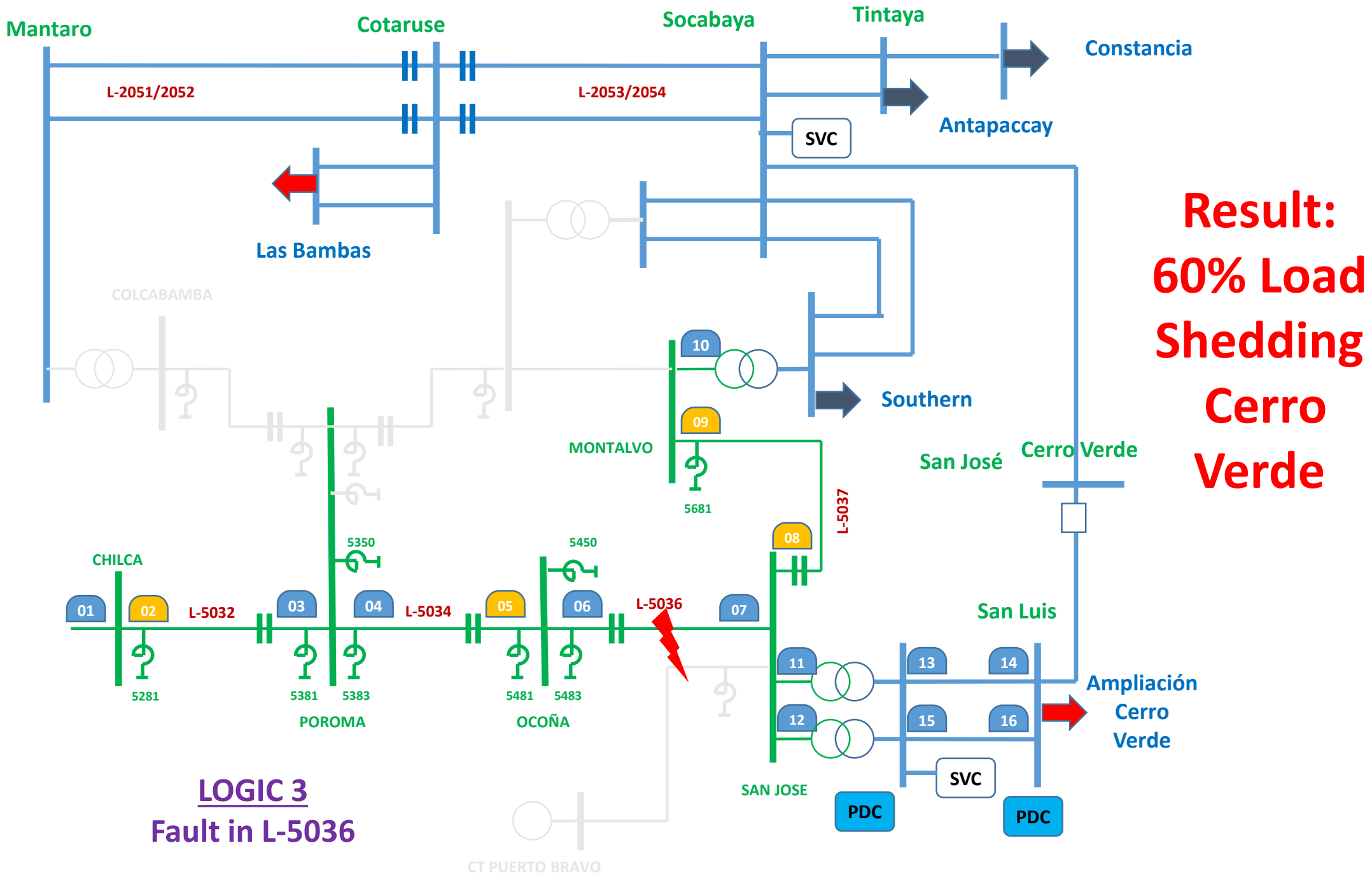
Result:
25% Load Shedding Cerro Verde

LOGIC 1
Fault in L-5032



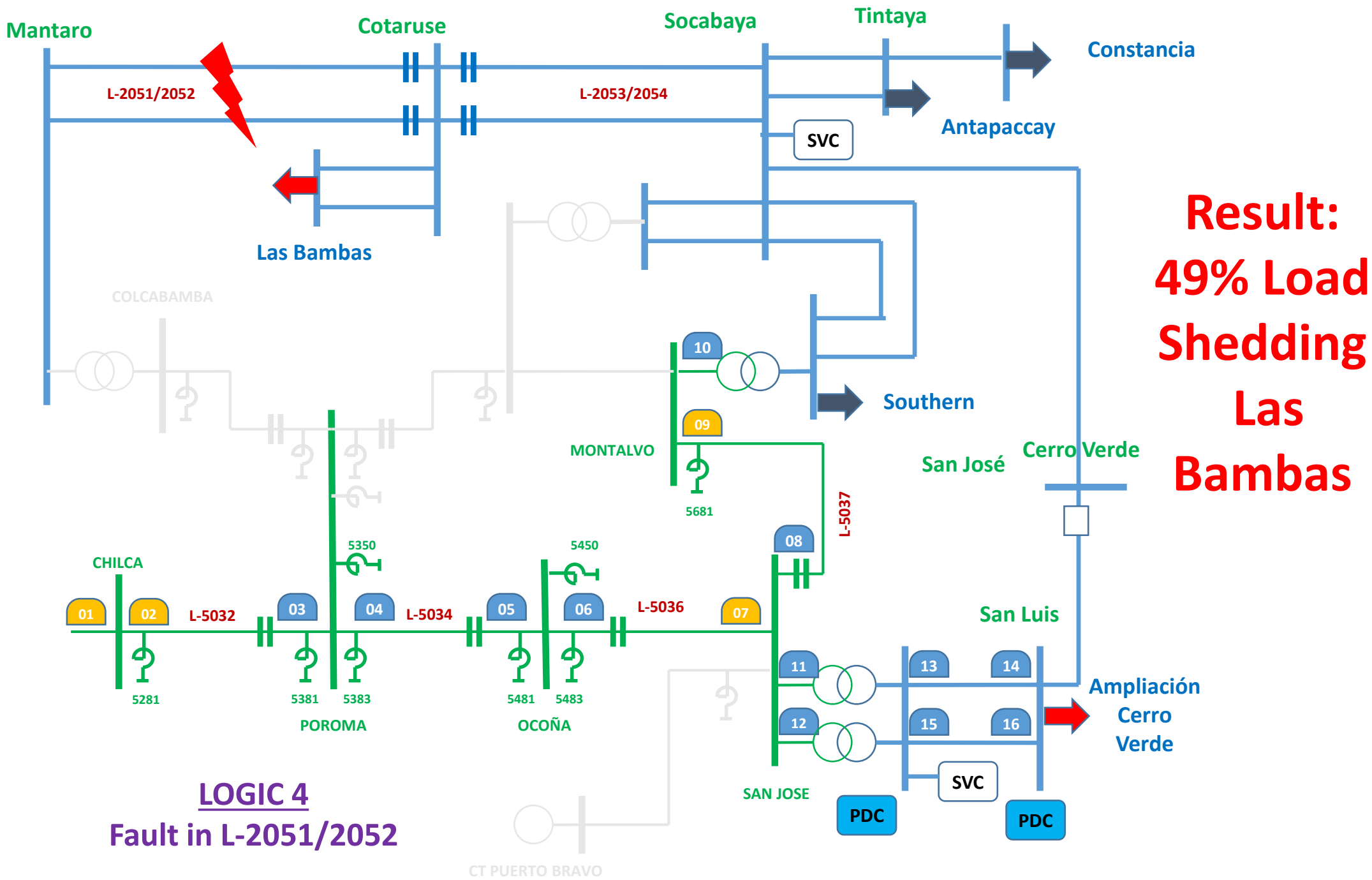
Result:
60% Load Shedding Cerro Verde

LOGIC 2
Fault in L-5034



Result:
60% Load Shedding Cerro Verde

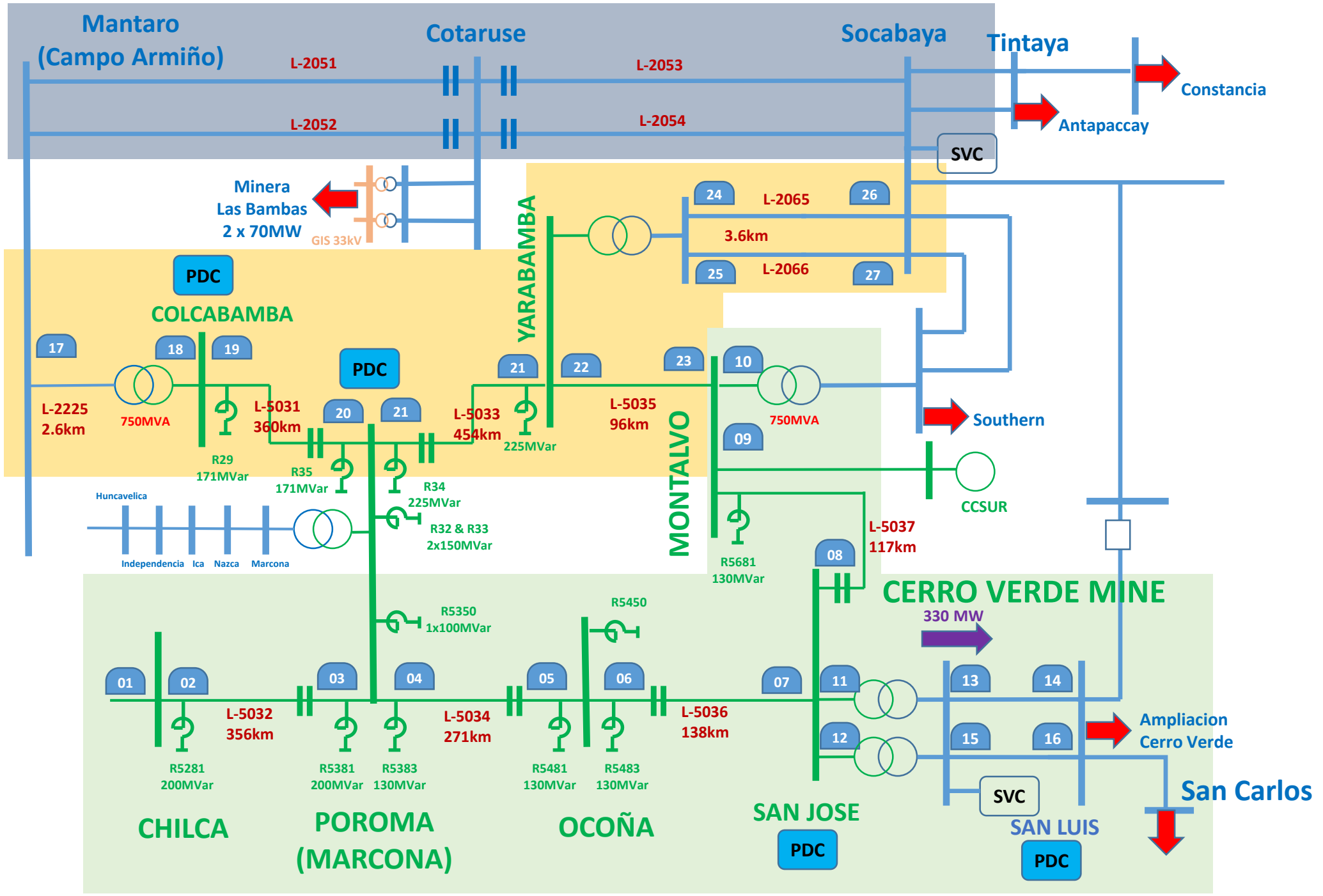
LOGIC 3
Fault in L-5036



Result: 49% Load Shedding Las Bambas

LOGIC 4

Fault in L-2051/2052


Mantaro
(Campo Armiño)
Cotaruse
Socabaya
Tintaya
Constancia
Antapaccay
L-2051
L-2052
L-2053
L-2054
SVC
Minera
Las Bambas
2 x 70MW
GIS 33kV
YARABAMBA
24
L-2065
26
3.6km
25
L-2066
27
PDC
COLCABAMBA
17
18
19
L-2225
2.6km
750MVA
L-5031
360km
R29
171MVar
PDC
20
21
R35
171MVar
R34
225MVar
R32 & R33
2x150MVar
Huncavelica
Independencia
Ica
Nazca
Marcona
21
22
L-5033
454km
225MVar
23
L-5035
96km
MONTALVO
10
750MVA
09
Southern
CCSUR
R5681
130MVar
L-5037
117km
08
CERRO VERDE MINE
330 MW
R5350
1x100MVar
R5450
01
02
03
04
05
06
07
11
13
14
12
15
16
Ampliacion
Cerro Verde
L-5032
356km
L-5034
271km
L-5036
138km
R5281
200MVar
R5381
200MVar
R5383
130MVar
R5481
130MVar
R5483
130MVar
SVC
San Carlos
CHILCA
POROMA
(MARCONA)
OCOÑA
SAN JOSE
PDC
SAN LUIS
PDC

Staging & RTDS (Real Time Digital Power System Simulation) of Cerro Verde's RAS

Project Results

- Testing included switching under máximum power flow conditions and disconnection of lines for maintenance.
- The time of operation of the scheme itself (PMUs, PDC, etc) was between 40ms to 80ms, this time includes the 50 milliseconds additional delay for coordination of logics 1, 2 and 3; and 150 ms for logic 4.
- The results were satisfactory and the system was commissioned December 2015.

Synchrophasors: Another Tool in Tool Belt