NASPI Working Group Meeting 2015

Successful Deployment Experience of a Synchrophasor-Based System Integrity Protection Scheme (SIPS)

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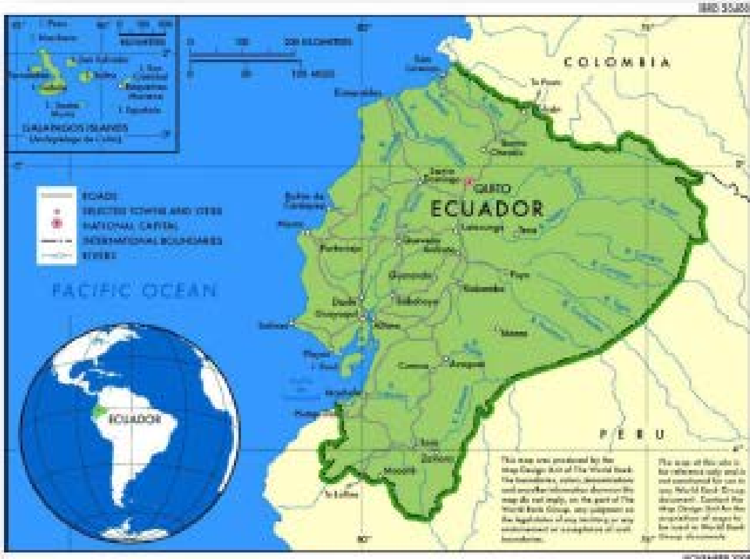
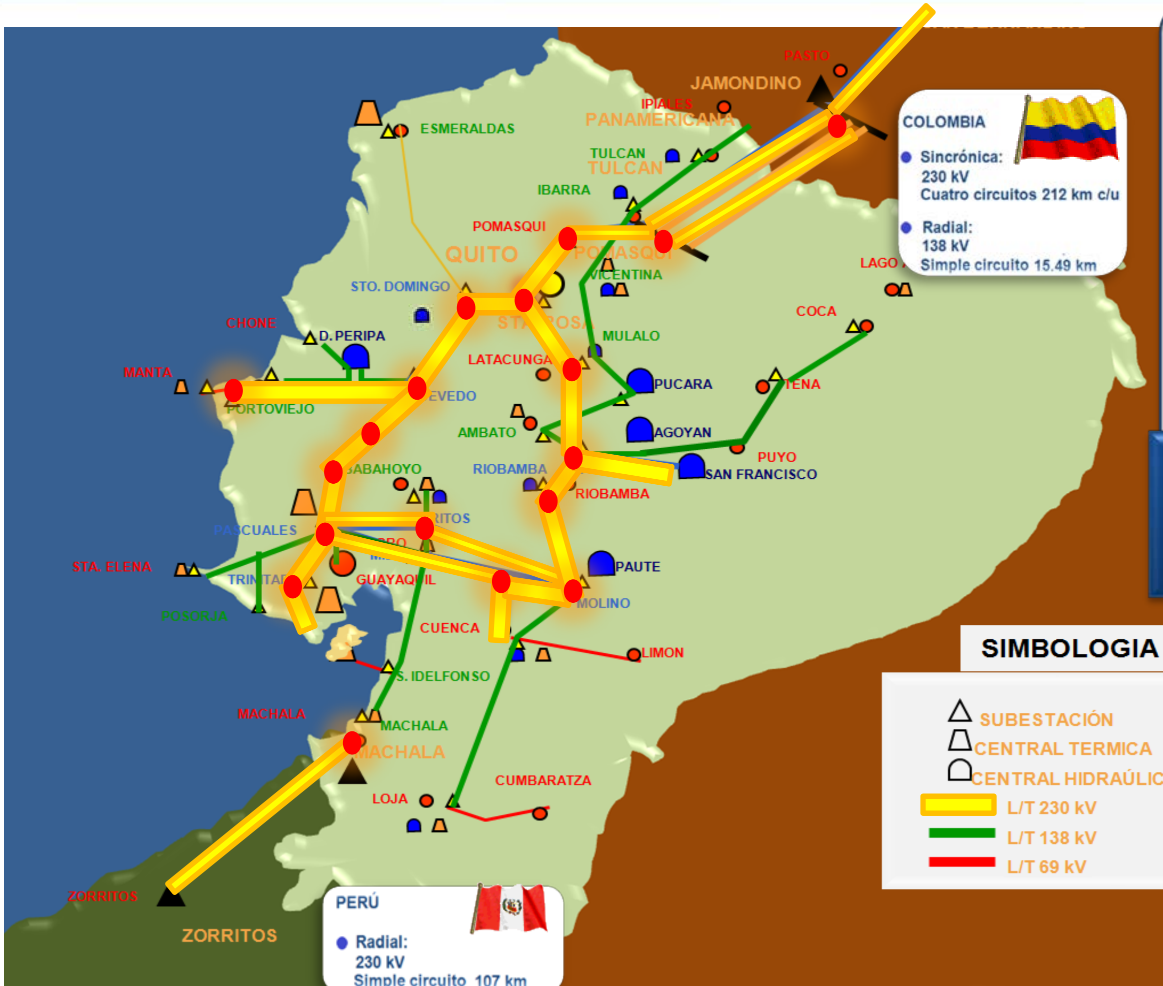
ECUADOR OVERVIEW

Ecuador



Location:	South America
Area:	283,561 km^2
Capital:	Quito
Population:	14,483,499 (2010)
Currency:	USD $

NATIONAL INTERCONNECTED SYSTEM



- **Renewable:** 2 444,39 MW
- **Non-Renewable:** 2 415,69 MW
- **TOTAL**: 4 860, 08 MW

Installed Capacity

- **Peak load:** 3502.6 MW
- **Energy Demand:** 20 882 GWh
- **Energy Production:** 21 460 GWh
- **Importation:** 824.5 GWh (3.8%)

DATA 2014

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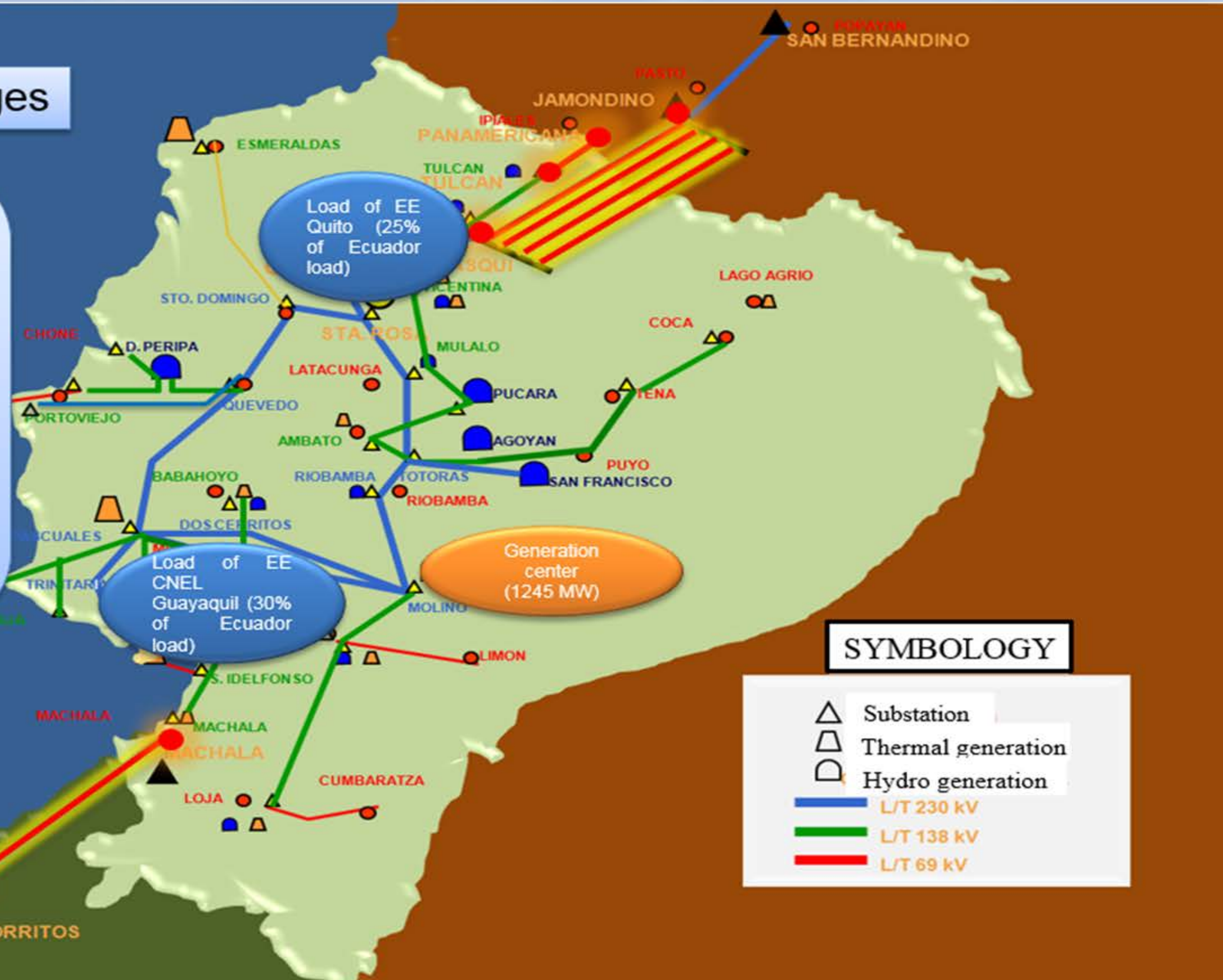
SYSTEM OPERATION OVERVIEW

Current operational challenges

Limited generation and transmission capacity which cause insufficient generation resources near the biggest consumption centers. Thus, there are some instances of overloading of certain transmission facilities, especially due to high power transfers from bulk generation in the central and southern areas to the main consumption centers in the northern (i.e. Quito) and southwestern (i.e. Guayaquil) areas, which entail congestion, unexpected generation outages, load shedding, and/or poor dynamic performance.



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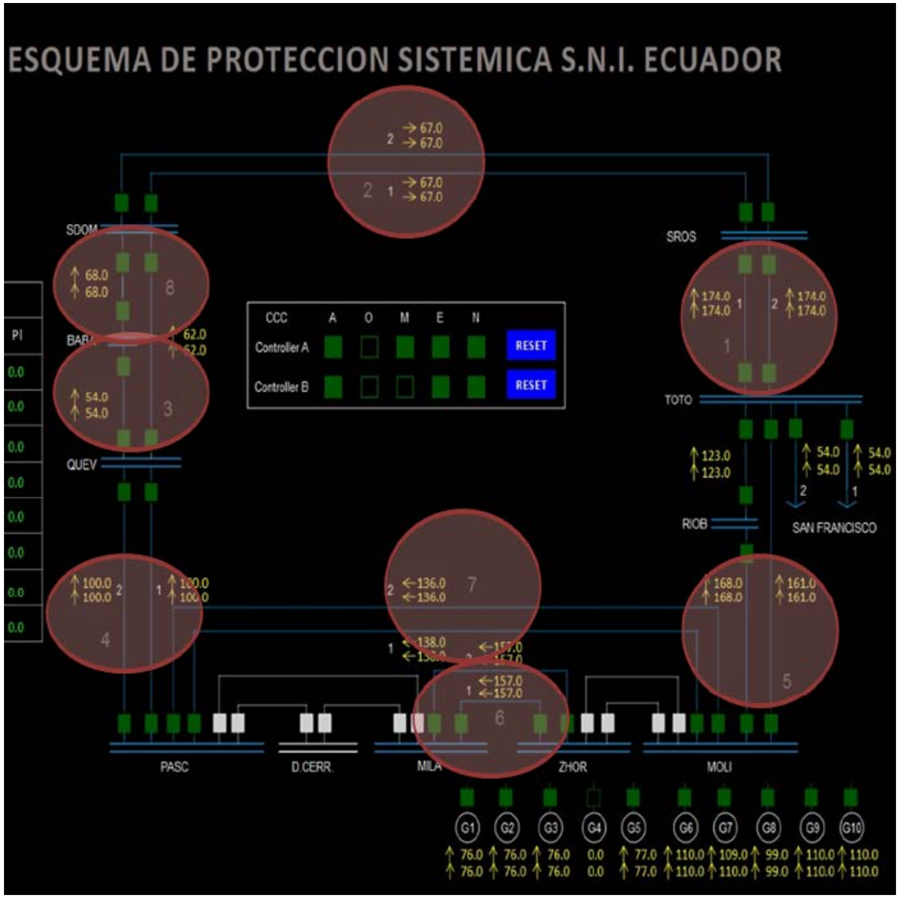
OBJECTIVE OF THE STUDY

Identify critical contingencies in the Ecuadorian National Interconnected System causing loss of stability.

Define the actions to minimize the risk of loss of stability upon the occurrence of double contingency (N-2).

Implement in the Ecuadorian power system a Synchrophasor-Based System Integrity Protection Scheme improving the reliability and security.



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IDENTIFYING CRITICAL FAULTS - METHODOLOGY

- Ecuador's power system was modeled in interconnected operation with the Colombian power system.
- The scenarios were defined: high and low hydrology generation, for periods of low, medium and high demand.
- The critical double-contingencies were identified with voltage and/or power flows that violate the limits of emergency operation.
- Define the tables of mitigation actions that suggest the place and the amount of load to be shed and generation to be tripped.
- The mitigation of any specific condition was carried out via SIPS central controller programming that allows sensing/monitoring and tripping/mitigating IEDs at suitable locations.




IDENTIFIYING CRITICAL FAULTS - EXAMPLES

CONTINGENCY	Electrical Problem	POLYNOMIAL FOR THE CALCULATION OF MITIGATION ACTIONS
Disconnection of two circuits of 230 kV Santa Rosa - Totoras	1) Angular instability with Colombia 2) Overloads 3) Low voltage	$DP0 = P1 + k1\_1 \times P2$ if $DP0 < Pset1\_1$, $DP = 0$; if $DP0 \geq Pset1\_1$, $DP = k1\_2 \times (P1 + k1\_1 \times P2 - Pset1\_2) + Pset1\_3$ $DPLoad = k1\_3 \times DP\_actual$ P1: Total prefault power flow of the transmission line Santa Rosa -Totoras P2: Prefault power flow of 138 kV transmission line Ambato - Totoras
Disconnection of two circuits of 230 kV Santo Domingo - Santa Rosa	**1) Angular instability with Colombia** **2) Low voltage**	**If $P < Pset2\_1$, $DP = 0$;** **if $P \geq Pset2\_1$,** **$DP = k2\_1 \times (P - Pset2\_2) + Pset2\_3$** **$DPLoad = k2\_2 \times DP\_actual$** **P: Prefault power flow of transmission line Santo Domingo - Santa Rosa**

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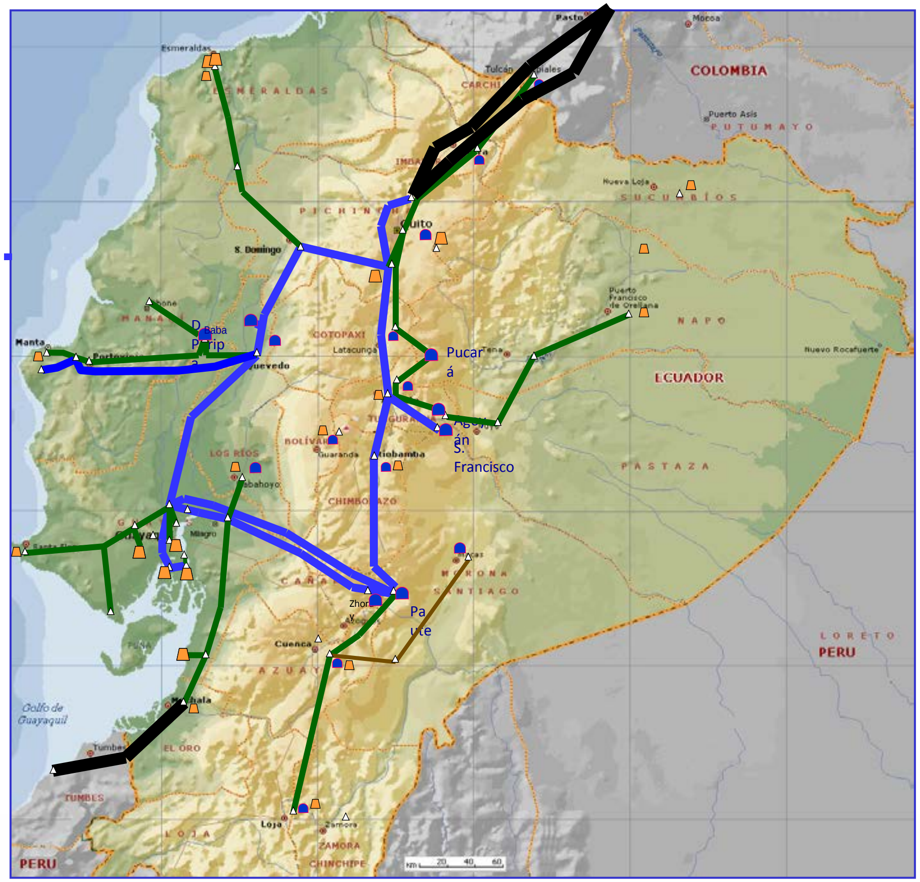
ECUADOR – System Integrity Protection Scheme SIPS

System Integrity Protection Scheme SIPS

The electric system, in a stressed state (with double contingencies in 230 kV ring), can cause a system collapse.

An Synchrophasor-Based System Integrity Protection Scheme (SIPS) has been implemented to mitigate the N-2 contingencies.

The SIPS was designed with high flexibility and expandability.



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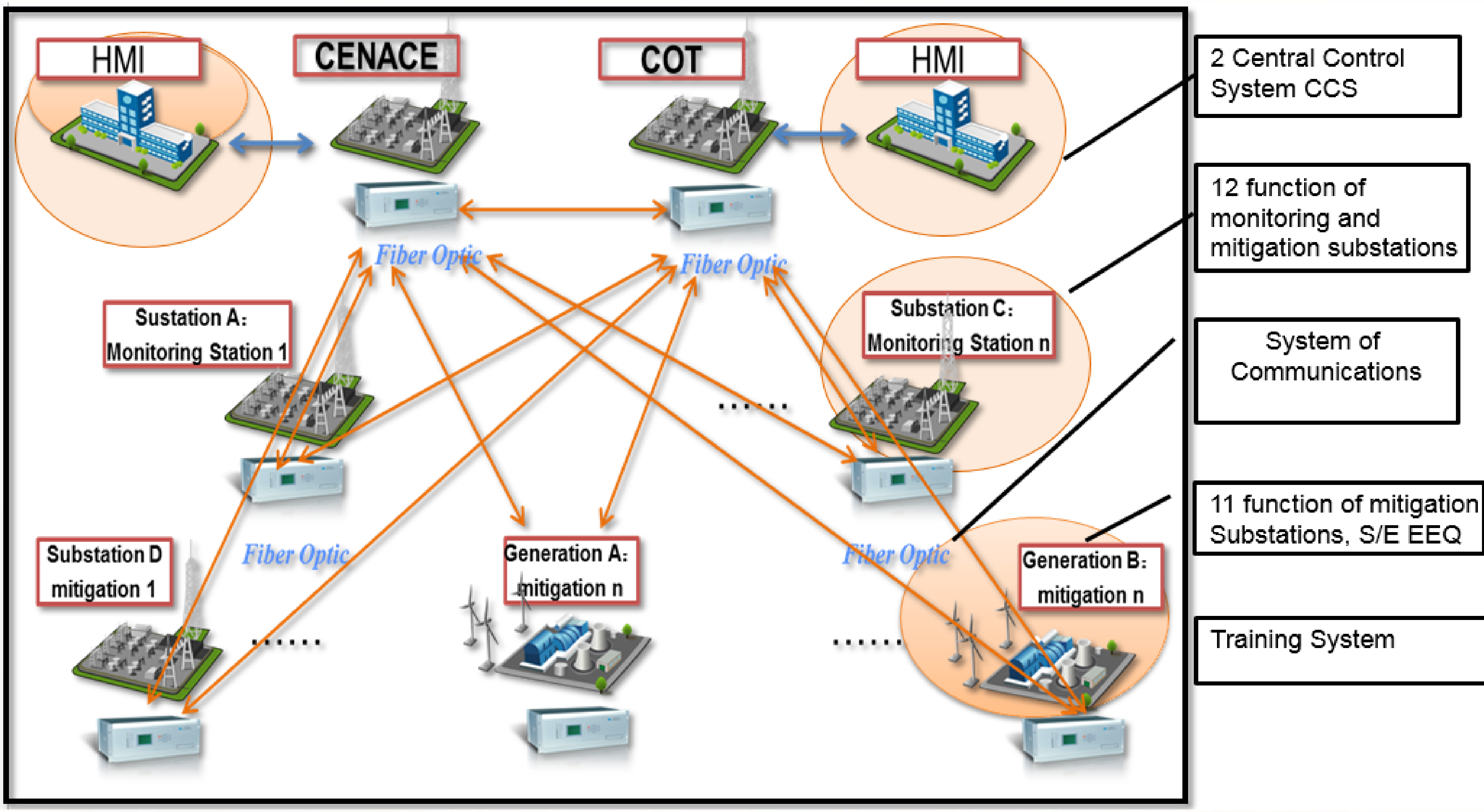
SIPS: STRUCTURE AND DESCRIPTION



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SIPS: CHARACTERISTICS

Runtimes of Ecuadorian SIPS

Process	Processing time	Accumulated time
Inception of Fault		0ms
Runtime of element relay Line breaker open	57ms	57ms
SPS monitoring relay	37ms	94ms
Communication channel	6ms	100ms
SPS controller	14ms	114ms
Communication channel	6ms	120ms
SPS mitigation relay	5ms	125ms
Breaker of generation/load	67ms	192ms

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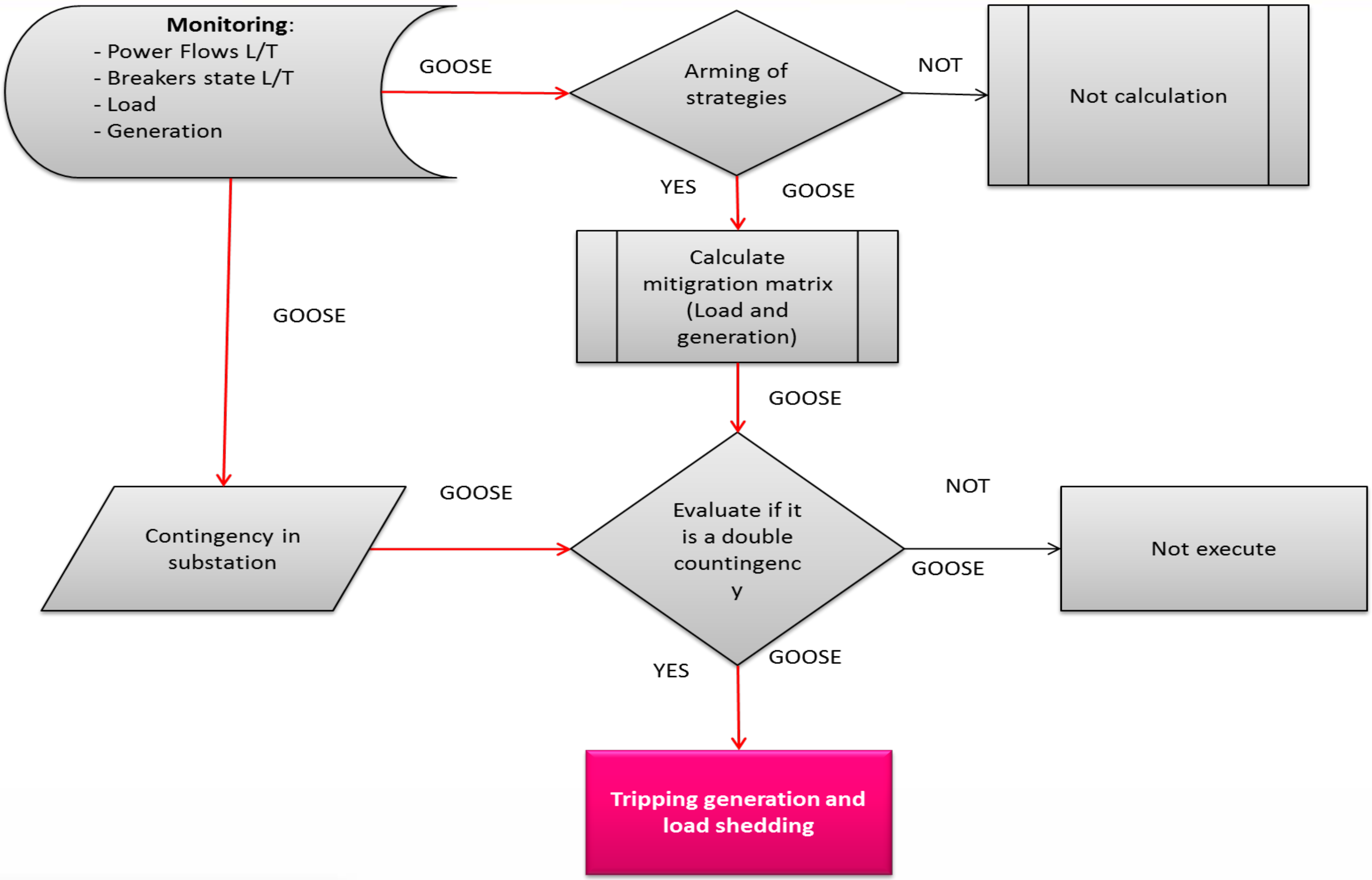
SIPS: FUNCTIONALITY



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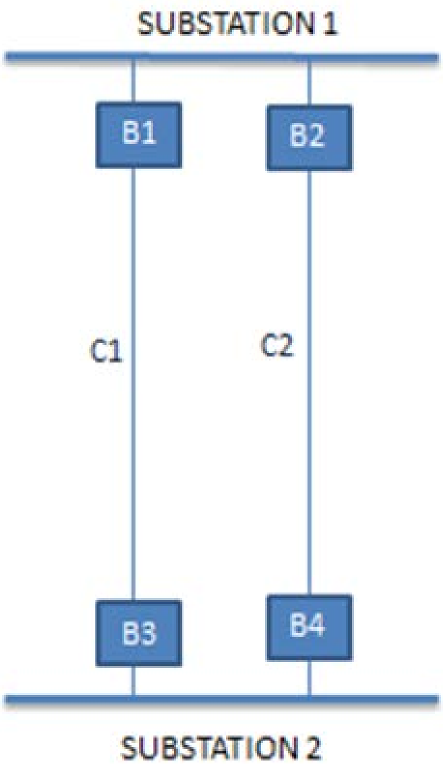
JUDGMENT IN THE CENTRAL SYSTEM OF N-2 CONTINGENCY



	Substation 1 Breaker 1	Substation 1 Breaker 2	Substation 2 Breaker 3	Substation 2 Breaker 4	Execute the mitigation actions
	1	1	1	1	YES
	1	1	0	0	YES
	0	0	1	1	YES
	1	0	1	0	NO
	0	1	0	1	NO
	1	0	0	1	YES
	0	1	1	0	YES




SIPS PERFORMANCE EVENT

POSTEVENT ANALYSIS

On May 6, 2015, at 1:29:54, SIPS is activated due to the double contingency of the Transmission Line ***Molino - Pascuales 230 kV***. It should be noted that this action corresponds to Strategy 7 of the SPS, which was already armed when the double contingency of the Transmission Line occurred.

The following table shows the condition that must be present in the system in order to activate the Strategy 7 of SIPS:

7	**Double circuit Molino – Pascuales 230 kV**	**Total power flow for the two circuits Molino – Pascuales 230 kV > 350 MW**

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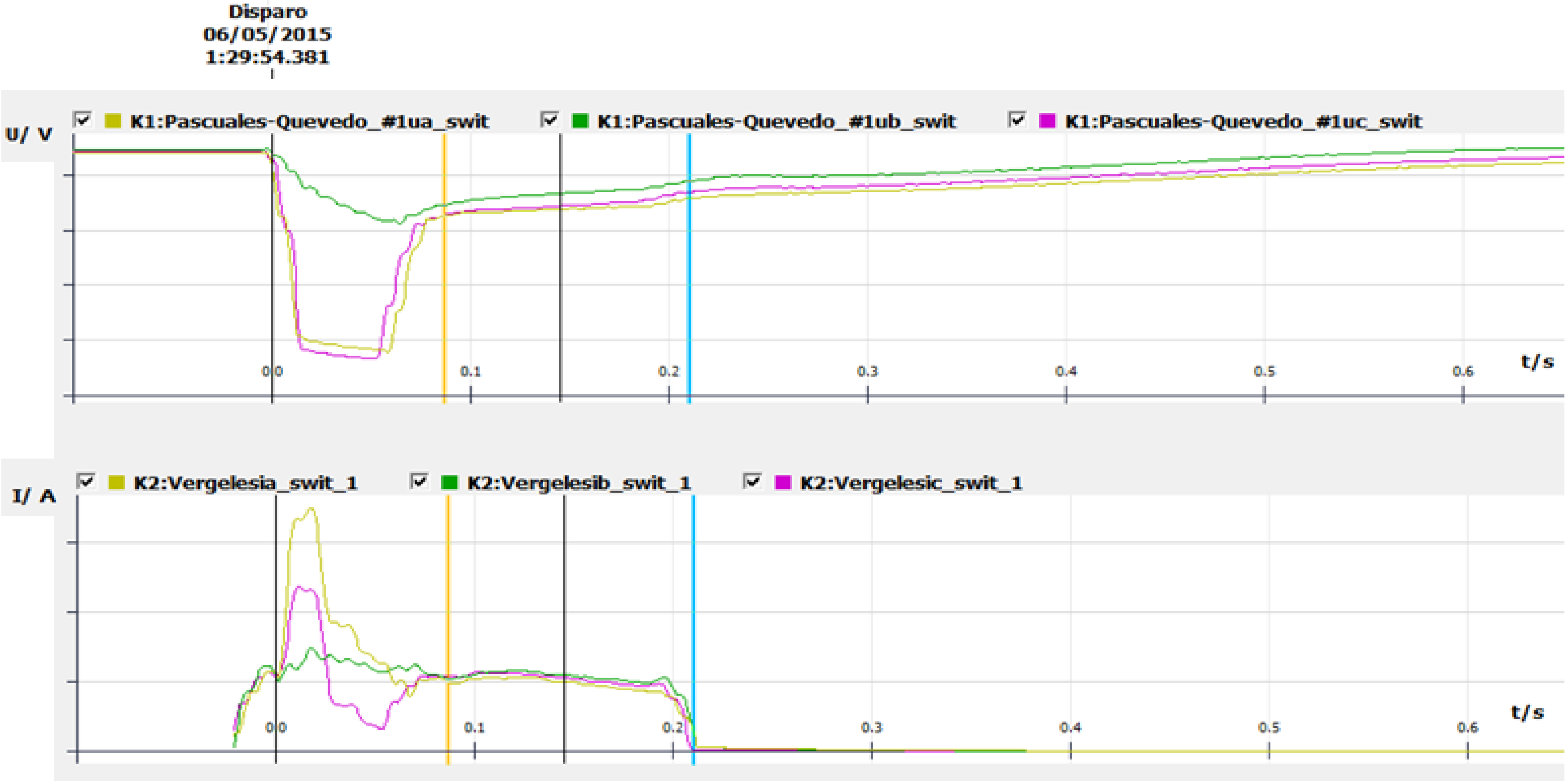
SIPS PERFORMANCE EVENT

EVENT ANALYSIS PERFORMANCE WITH SIPS



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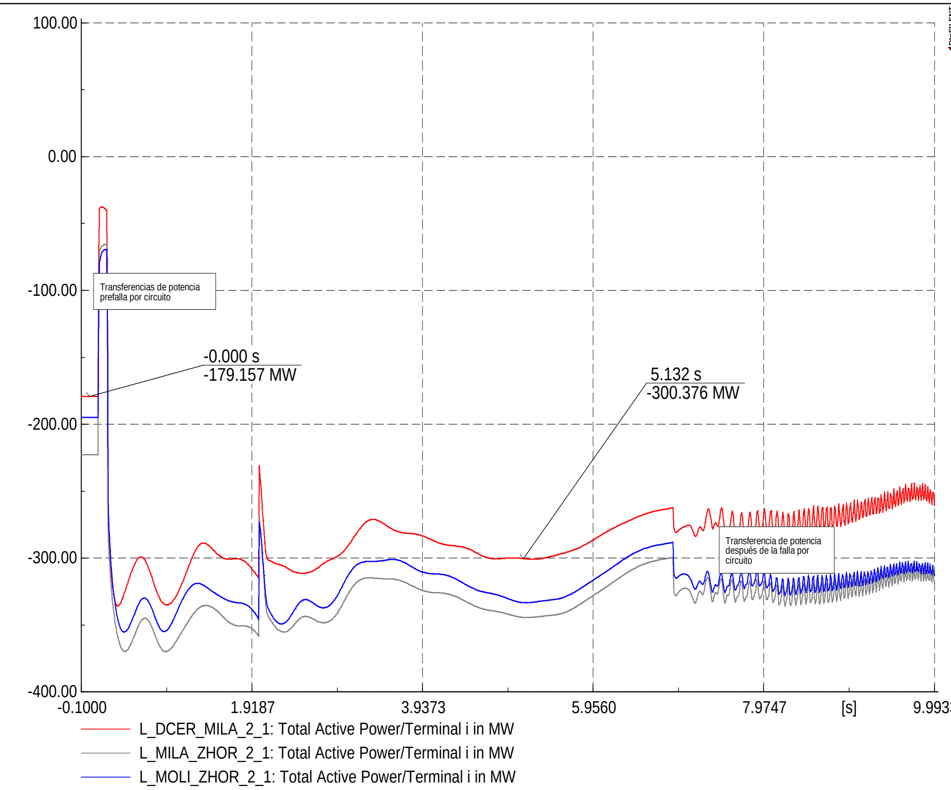
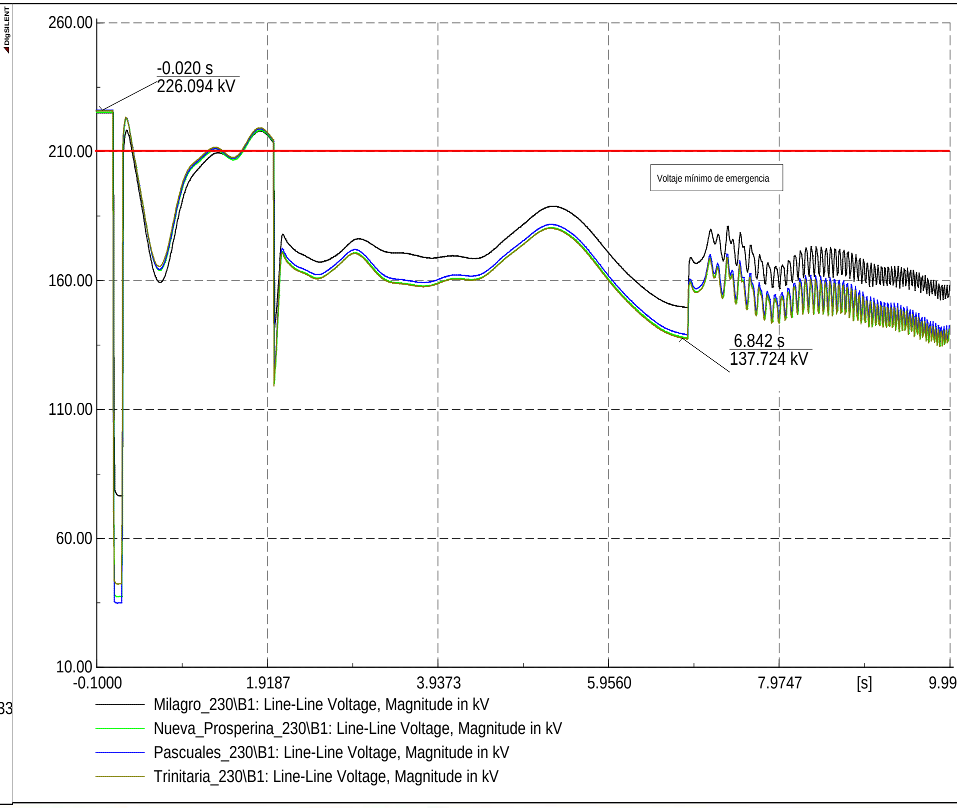
SIPS PERFORMANCE EVENT

EVENT ANALYSIS PERFORMANCE WITHOUT SIPS





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SIPS PERFOMANCE EVENT

Calculating the Cost of Energy Not Supplied <u>WITH</u> and <u>WITHOUT</u> SIPS

	ENS (MWh)	Total Cost by ENS (Millons USD)
WITHOUT SIPS	825,00	1,20
WITH SIPS	89,20	0,14

Economic savings due to performance of the SIPS	**1,1 Millones de USD**

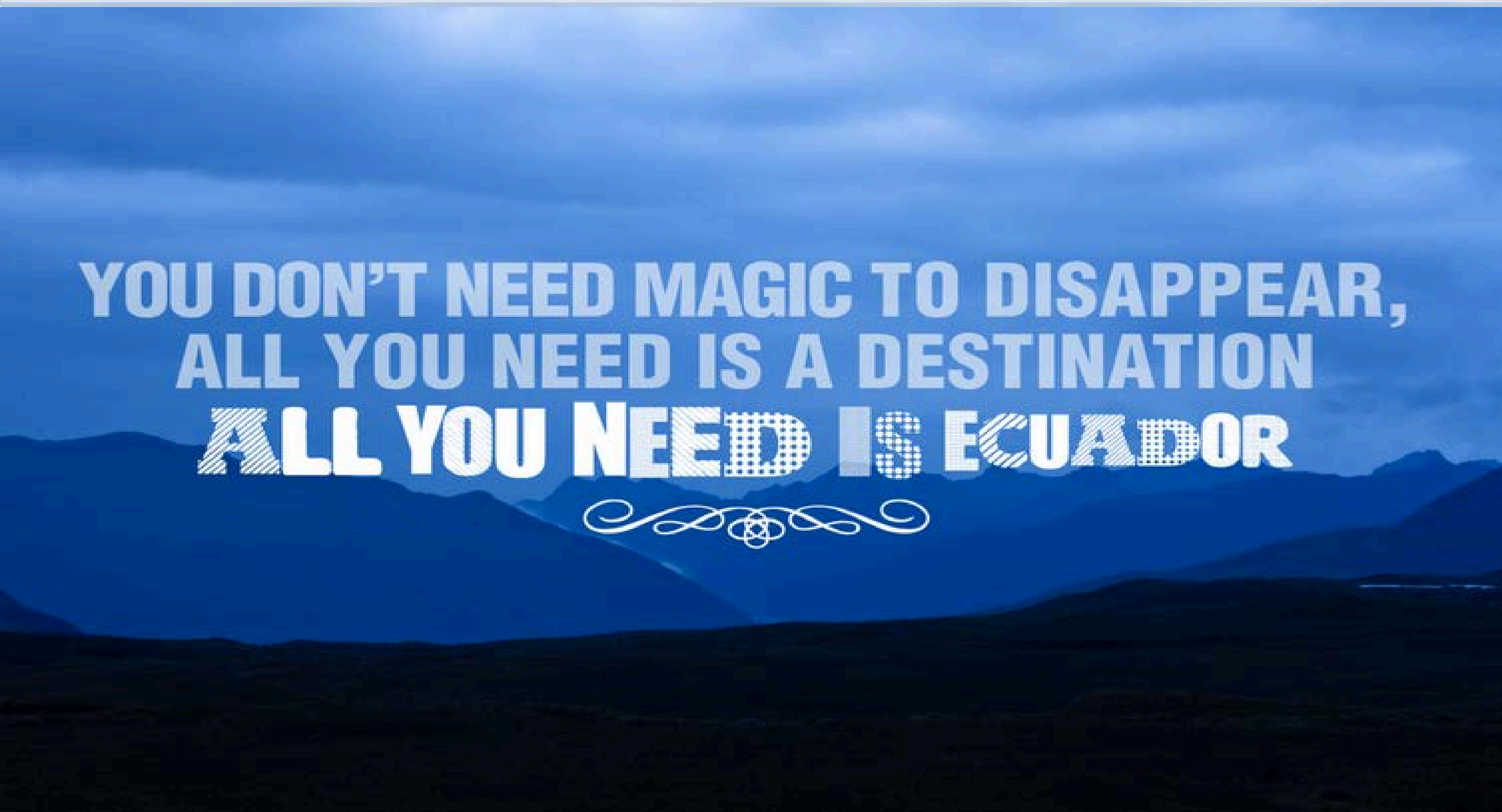
Cost of Energy Not Supplied (CENS), approved by the CONELEC on April 14, 2011, it has a value of 153,30 ctv. USD/kWh or 1533,00 USD/MWh




CONCLUSIONS

- SIPS provides greater security in power system operation upon the occurrence of critical contingencies, previously identified and included in this system.
- With the operation of the Ecuadorian SIPS, some restrictions on generation dispatch are no longer necessary to consider.
- The obtained results, especially the field measured action time, fully complies with the defined specifications.
- The settings of SIPS should be frequently tested, especially with topological changes of the transmission network, operation start of new generation plants and/or demand growth.



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