



## II. DESCRIPTION OF SIMULATOR

The simulator is a set of software modules that run under Windows platforms, which interact with each other and with external data files with the following objectives:

- 1- Get the data (parameter tables and measures) to feed the logic of RAS.
- 2- Verify the validity of the above data and replicate the performance of the system based on these.
- 3- Check that the electrical system respond adequately to the actions taken by the RAS way.

It consists of the following main modules:

- Tables Creation
- PSSE Data Readings
- Logic Run (PSC, DAR-Qc, DAL, DAD)
- *Apply Contingency*
- Simulator Run
- Graphics

### A. Tables Creation

The objective of the logic that calculates the amount of load to shoot in MW for contingencies that produce overloads or stability problems, is to shoot the right amount of power to leave a particular equipment with a power flux equal to its limit (thermal or stability limit).

In the formula for determining the amount of load, are involved the distribution factors of the equipment defined as contingency regarding the equipment that are overloaded (critical equipment). That is, the increase in flow for critical equipment prior contingency.

There is another type of factor, which we call alleviation factor, which represents the effect produced by the release of a load on the critical equipment when contingencies occur.

These factors are entered as tables in CSV format and depend on critical equipment to be monitored and the status of the pre-contingency system.

For the calculation of these factors scheduled Python module that interacts with the model of the grid in PSSE (electromechanical simulation program) is used.

This module covers all states of the system by means of which the RAS provides a solution in case of a contingency occur. This module prepares PSSE files to reflect each state and calculate the distribution and alleviation factor for each contingency and critical equipment to be monitored. PSSE functions are used for this purpose.

This module must be run prior to the other because the result of its execution (distribution factors and alleviation factors) are inputs for the implementation of RAS and other modules of the simulator.

Once factors are calculated remain unchanged until the system topology changes. When the network evolves and the new

configuration is not considered in the states this module must be run again and tables of factors updated .

### B. Read PSSE Data

In the formula that determines the amount of load to shed when contingencies occur, the power flow through the 500kV equipment and the critical equipment is considered.

To know the stations needed to complete the total amount of load to shed is necessary to know the load of each stations involved in the DAC.

To determine the status of the system is necessary to know whether equipment is in service.

To determine how much reactive power can be quickly get out of service to regulate voltage in the system when serious contingencies take place is necessary to know what reactive elements are in service.

All these data are obtained on the RAS system using relays synchrophasor functionality that allow the measures very quickly and reliably.

To emulate the real data acquisition a python module was programed, obtaining this information from PSSE files, which represent the state of the network at a given moment.

As is founded a solution to the infinite possible states considering a finite number of cases, it is necessary to obtain multiple base cases with different scenarios of generation, international exchanges and demand, ensuring that these are as representative as possible a set of scenarios.

'Read Data PSSE' module is executed each time that the performance of RAS is simulated for a different scenario (each time you change base case).

### C. Logic Run (DAC-General, DAC-Balance, PSC, DAR-Qc, and DAD DAL)

So to test the operation of the logic programmed in RAS, several modules that use the data resulting from the programs described above were implemented.

These logics are implemented through a central module programmed in the same language (Run Logic).

#### *Logic DAC-General*

The DAC-General logic calculates the amount of load to shed in MW for contingencies that produce overloaded or stability problems. The purpose of the formula is to leave the more charged critical equipment at the limit of its capacity.

Inputs for this module are the flows for critical equipment, flows by the 500kV equipments that define the contingency, distribution and alleviation factors, and rates of critical equipments.

After selecting the state this module is executed for the contingencies that take place overloading equipment.

#### *Logic DAC-Balance*

DAC-balance logic calculates the amount of load to shed in MW for contingencies that require a large part of UTE electrical system is disconnected from the electrical system of

Argentina. The idea of the DAC-balance formula is to shed the exact amount of load to achieve a balance between demand and generation of Uruguayan system.

Inputs for this module are the power flow through the equipment that connects Uruguay system with Argentina.

After selecting the state this module for contingencies that produce imbalance load-generation runs.

#### *Logic DAD*

DAD is the logic that executes changes in the exchange of active power through the frequency converter (CME). The purpose of this logic is to modify the exchanged active power to decrease the amount of load to disconnect.

#### *Logic PSC*

Once the amount of load to shed is calculated running this logic selects the stations to be disconnected to meet the calculated load.

#### *DAR-Qc*

DAR-Qc logic calculates a reactive power compensation that helps voltage control post-contingency.

Inputs for this module are reactive flows through 500kV equipment that define the contingency, the amount of load shedding and the state of the reactive elements in the system.

#### *Logic DAL*

The logic DAL intentionally disconnect transmission lines in order to separate islands systems.

Input to this module is the contingency and the system state.

The result of the execution of the described logics is a text file which specify for each contingency: selected stations, the power change in the CME, and the lines and capacitors to be disconnected.

#### *D. To apply contingency*

This module is programmed in Python which simulates the contingency and the RAS responses. Dynamic simulations in PSSE are used to achieve this.

In this module all actions are carried out that result from applying the logics described in the previous section.

As a result of the implementation of this module, text files containing the evolution of pre-selected variables of interest in a fixed time window are generated.

#### *E. Simulator Run*

This module programmed in Python has as input the PSSE base cases to be analyzed, and run the modules described above for each one.

#### *F. Graph*

This module programmed in Matlab gets as input text files resulting from the execution of the routine "Simulate" and performs graphics in PDF format for different variables to analyze the contingency solution (active and reactive power, voltage, frequency, machines angle, etc.).

### III. FINDINGS AND CONCLUSIONS

The simulator is currently being used to calculate csv tables that are inputs to the logics operation of the RAS that is being implemented, and analyze the results of actions taken in case of 500kV contingencies in the system.

An example of the main results of execution of the simulator is presented below.

Table 1 shows part of one of the distribution factors tables resulting from the implementation of the module "Creating Tables". It corresponds to the distribution factors for contingencies 10, 11 and 12 (double contingencies of 500kV lines that interconnect Palmar station to Montevideo) in the states 1, 2 and 3. State 1 corresponds to the network with all its equipment in service.

		Contingencia				
		...	10	11	12	...
Estado	1	...	0.644934	0.644934	0.862	...
	2	...	0.644934	0.644934	0.862	...
	3	...	...	...	...	...
	...	...	...	...	...	...

Table 1: Distribution factors

The presented results for this paper correspond to an scenario with 1000 MW of hydraulic power, 200 MW wind power, 600 MW thermal and power exchanging with Brazil. The UTE demand is 2000MW.

Figure 2 shows the result of the implementation of "Run Logical" module for BR5-MB5 + PA5-MA5 contingency. It is noted that a shedding 781,9MW (executed by individual stations and part of the transmission network shedding) is required. Also a decreasing exchange trough CME of 100MW is required in this state.

It can be seen that the limiting equipment (the device that requires greater shedding) is the PAL-ROD line. To disconnect five capacitor banks is also necessary to avoid unacceptable overvoltages after the shedding of load.

```

*****
cont - 11
DACo CE State R DAC DAD finalDAC
679.1 PAL-ROD 1 1 779.1 -100 781.9
Loads selected by PSC logic
MVE
TRI
0
Lines selected by PSC logic
MVA-BIF_1
MVA-BIF_2
MVE-MVJ_1
MVE-MVJ_2
MVE-MVF
MVE-MVR
MVI-MVH_1
MVI-MVH_2
MVI-MVH_3
MVI-MVF
MVI-MVR
TrSC5
0
DAD selected by DAD logic
-100
0
Lines selected by DAL logic
0
Time delay selected by DAL logic
0
0
Capacitor banks selected by DAR_Qc logic
MIS_030_BCO_BC1_INT
MIS_030_BCO_BC2_INT
MIS_030_BCO_BC3_INT
MIS_030_BCO_BC4_INT
MIS_030_BCO_BC5_INT
0
*****
    
```

Figure 2: Actions to be taken resulting from "Logic Run"

Figure 3 shows the evolution of flows by ROD-PAL, PAL-BAY lines. It can be seen that the most loaded equipment after RAS actions is ROD-PAL line, which is the limiting equipment in this case. The equipment final flow is its thermal load capacity for one hour (124.7MW).

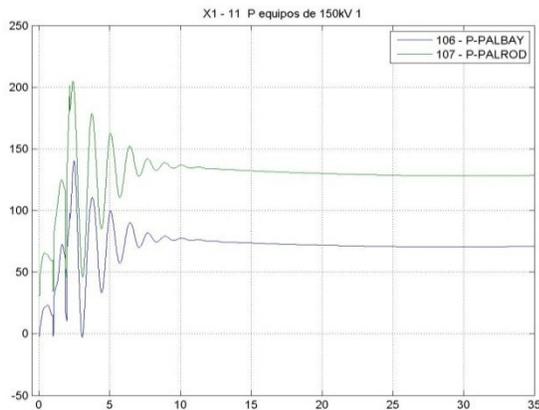


Figure 3: 150kV Power Team

Figures 4 and 5 show the evolution of angles of hydraulic machines and voltages in the system of 500kV.

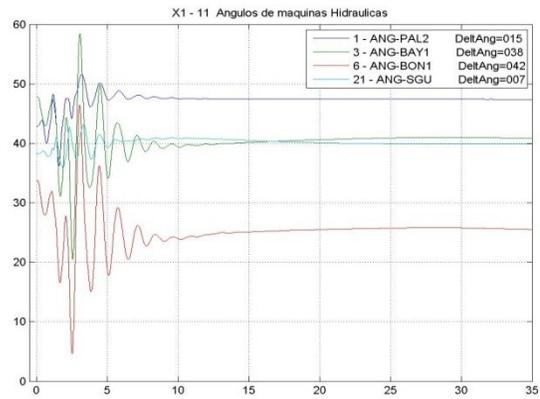


Figure 4: Angles hydraulic machines

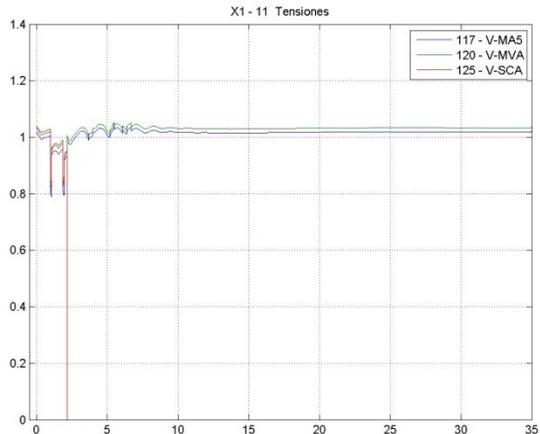


Figure 5: Tensions in 500kV system

To have a tool that simulate the behavior of the RAS system and the evolution of the power system in contingencies, allow to verify the effectiveness of actions to take and adjust the data to load into the RAS in order to get the best performance

#### IV. REFERENCES

[1] Julián Malcón, Nicolás Yedrzejewski, Ashok Balasubramanian, Rameez Syed, and Sai Krishna Raghupathula, "Implementing a Country-Wide Modular Remedial Action Scheme in Uruguay," *Western Protective Relay Conference (WPRC)*, October 2015.

#### V. BIOGRAPHIES

**Sebastián Beledo** was born in Durazno, Uruguay, on June, 1981. He graduated in Electrical Engineering (2009) from Universidad de la República, Uruguay. Since 2012 he work as Dynamic Studies Expert at the National Dispatch Center , UTE.

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