Implementation and Tuning of the Automatic Generation Control in the Energy National Control Center of Ecuador - CENACE

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Abstract - **The Automatic Generation Control – AGC has as the main objective keep the system frequency and the net interchange in the tie lines near to their scheduled values through generation set points in the units conditioned to this purpose. Consequently, the AGC implementation requires a careful process of tuning and testing of the remote control devices for generation units and the AGC program installed in the Electric Market Administrator.**

Keywords- **SCADA, Automatic Generation Control, implementation, testing, tuning.**

I. Introduction

The Energy National Control Center – CENACE is the Wholesale Electric Market Administrator responsible for coordinating the secure and economic operation of the power system and international electric interconnections and for providing the required quality of electrical energy service.

The Ecuadorian power system has the following characteristics: 2401 MW of maximum demand, 12360 GWh of energy consumption per year, the 65% of the generation is hydroelectric and the 35% is thermoelectric, there is an electrical interconnection between Ecuador and Colombia with a transfer capacity of 250 MW.

In order to perform the real time operation of the power system, CENACE has a SCADA/EMS operative since 1995. The electric market evolution implies new technology requirements; consequently, CENACE is implementing a state of the art SCADA/EMS which includes the AGC functionality.

II. CENACE's AGC Description

A. Architecture and Interfaces

The figure 1 shows the AGCs' interfaces for its normal operation.

The AGC requires the next SCADA's telemetry data: the breaker status and the local-remote indication for each generation unit, the active power of each generation unit, the system frequency and the active power in the tie lines. The generation set points are also send through the SCADA.

The economic dispatch provides the economic base points for the generation units, the scheduled interchange in the tie lines is also provided by economic dispatch. The interface between AGC and economic dispatch permits the regulation cost minimization.

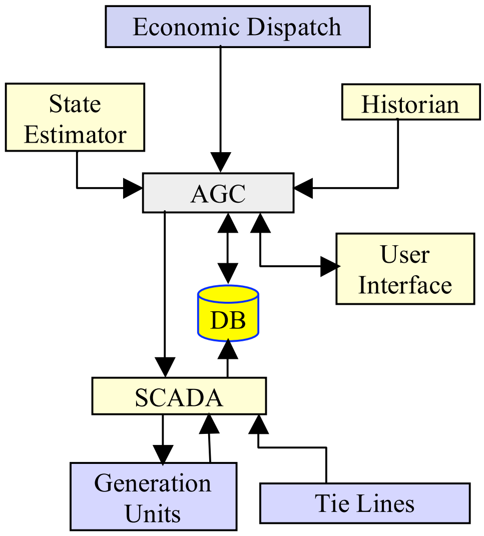

Fig. 1. AGCs' Interfaces with other subsystems

The interface between AGC and historian permits the AGC performance monitoring according to the NERC's standards. The behavior of each AGC variable is monitored at any period by trending.

The state estimator provides the AGC the network topology and the equipment distribution when the power system splits in multiple islands. Additionally, alternate measures are provided by the state estimator.

The user interface permits the operator execute the manual entries, select the unit control modes and set the correct parameters according to the demand period.

B. Signals Processing and Control Execution

The main activities of AGC in order to reach its objectives are:

- Get and filter the next real time measures: frequency, time error, active power in generation units and interchange in the tie lines.
- Calculate the Area Control Error – ACE according to the AGC control mode. The ACE quantifies the amount of regulation required from the generation units.

- Determine the desired generation for each generation unit according to the selected unit control mode.
- Sent generation set points to each generation unit and monitor they response.
- Verify the amount of regulation reserve is enough and issue and alarm if there is a shortfall.
- Monitor and record the AGC performance according to the NERC's standards.

C. Generation Unit Control Modes in CENACE's AGC

The more used unit control modes in CENACE's AGC are (1):

- MANUAL, the units in this mode are online, but can be controlled only by the local power plant operator.
- BASELOAD, a unit in this control mode will operate at a predefined basepoint specified by the operator, so the unit in this mode is controlled by AGC but does not contribute to system regulation.
- TEST, the operator can specify a set point and the test duration as a number of consecutive AGC cycles.
- Schedule, the units in this mode fixes its output in the scheduled value for every hour, the above mentioned value are taken of the economic dispatch.
- AUTOMATIC, a unit in this control mode is controlled by AGC in order to reduce the ACE to zero.

III. AGC Tuning Process

A. Initial Preparation

The first step is to verify the correct processing by SCADA for all the primary and alternate AGC signals.

Using the TEST mode verify the communication between the remote terminal unit and the CENACE's control system. The generation set points sending have to be verified, using the same control mode for each generation unit able to participate in the AGC. The Ecuadorian hydro power plants included in the tuning process are: Paute, Pucará and Agoyán.

B. Tuning for each Generation Unit

The sequence during generation units tuning is:

- Deactivation of the no-tracking logic in order to avoid the generation unit could be blocked during the test period.
- The real ramp rate, using generation set points, has to be determined. The unit base mode could be used for this purpose which allows the operator entering manually a desired basepoint and the unit reaches that value at its maximum ramp rate.

The average ramp rate values recorded during the generators tuning is presented in the table 1. The figure 2 shows the unit response trace which is useful to determine the real ramp rate for each generation unit.

TABLE 1
AVERAGE RAMP RATE OF THE TUNED GENERATION UNITS

Power Plant	Generation Unit	Ramp Rate MW/min
Paute	Unit 1	14.10
	Unit 2	13.30
	Unit 3	12.05
	Unit 4	11.40
	Unit 5	13.20
	Unit 6	14.60
	Unit 7	14.57
	Unit 8	12.75
	Unit 9	13.83
	Unit 10	14.40
Pucará	Unit 1	6.33
	Unit 2	6.56
Agoyán	Unit 2	5.75

- Adjusting the ramp rate parameter for each generation unit in the AGC.
- Verifying that each generation unit response changes according to the desired generation from AGC.
- To verify that the interface with the economic dispatch is working appropriately and entering the generation schedule for the next 24 hour.
- To verify that each of the control modes of the units in AGC operates in accordance with its specifications.

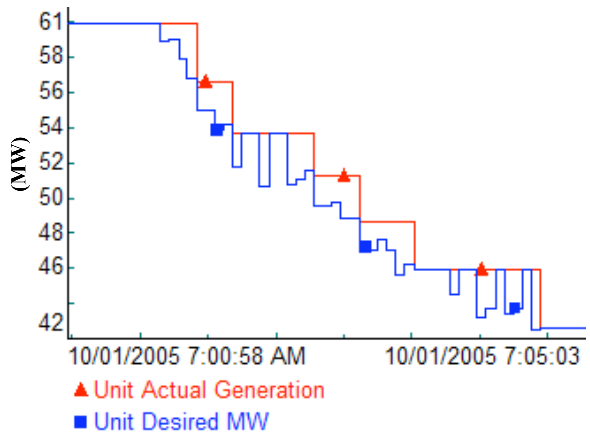

Fig. 2. Generation Unit Response under AGC

C. AGC Tuning as a System

This phase is initiated as soon as there was concluded the individual tuning of the units and it was demonstrated they were in aptitude to execute the regulation of suitable form. This phase involves the adjustment of AGC's parameters at application level and affects the performance of the whole system. The change of the parameters must be realized sequentially and with one parameter at once.

The target of this phase is to prevent overregulation in the generation units, which can be observed as oscillations in the ACE or the opposition between raw and filtered ACE (2).

For the tuning of the AGC as system and before incorporating of sequential form the generation units, the following conditions must be fulfilled:

- To verify that the economic dispatch for each unit has been updated correctly through the corresponding interface.
- To verify that the values of scheduled frequency and scheduled interchange are the correct ones.
- To verify that the control mode of the AGC is the correct one. The available control modes in the CENACE's AGC are: Constant Interchange CI, Constant Frequency CF, Tie Line Bias TLB, Tie Line Time Bias TLTB and Constant Frequency Time CFT.

Once the generation units have the corresponding permissions, a specific unit control mode has to be selected. It is necessary to make sure that a suitable number of units is taking part in the regulation depending on the demand conditions.

The critical variable to be monitored in this stage is the ACE, the parameters to be adjusted correspond to those related to filtering logic. A correct tuning will guarantee that the control commands on the units are as smoothed as possible for all the bands of demand.

The above adjustment process is facilitated by means of the graphic representation of the row and filtered ACE behavior by means of the historian system or others. The figure 3 shows the ACE behavior in normal conditions of operation.

The unit participation factors are calculated automatically in base of its regulation margin and its ramp rate.

Finally, the limits of the ACE that determine the operation of the AGC in normal and emergency as well as the AGC trip are adjusted, these values are assigned based on the experience in the power system operation.

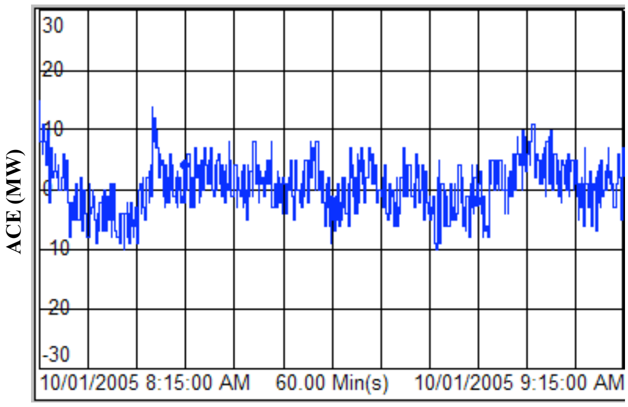

Fig. 3. ACE Behavior in Normal Conditions

IV. RESULTS

The following indicators help to make sure that the global AGC tuning process is correct:

- The ACE was graphically represented and analyzed during the test periods, it has an average of 5 zero crossing every 10 minutes. The ACE varies within a band of ±10 MW. Consequently, according to the NERC the AGC is performing a good control.
- The response of the generation units to the AGC requirements neither is oscillating and sudden changes nor appears, but in a soft way the units execute the regulation to take the ACE to zero.
- The net interchange in the electrical interconnection with Colombia keeps stable in a 5% variation band with respect to its programmed value, which is acceptable according to the operative binational agreement.
- The system frequency is kept inside a band of ±0.06 H, in normal conditions; the maximum allowed frequency deviation according to the Ecuadorian regulations is ±0.15 Hz in normal conditions. The figure 4 shows the behavior of the frequency in normal conditions.

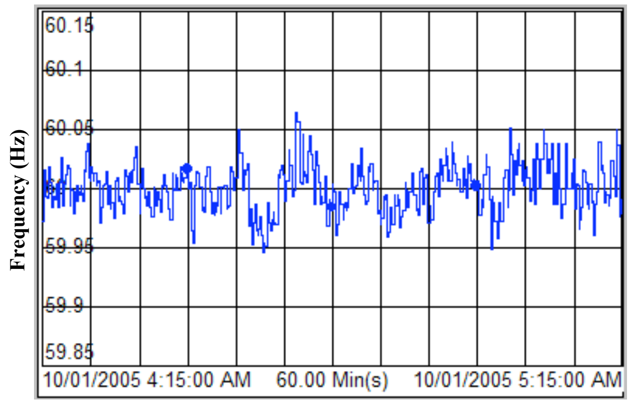

Fig. 4. System Frequency Behavior in Normal Conditions

- The good performance of AGC was demonstrated during a 72 MW plant trip in the peak demand period. The minimal registered frequency value was 59.91 Hz and the nominal frequency was recovered within 50 seconds approximately. The figure 5 shows the ACE behavior and its rapid recovery in emergency conditions.
- The values of economic dispatch were successfully executed by units in SCHEDULE mode and all the other unit control modes gave the expected results.

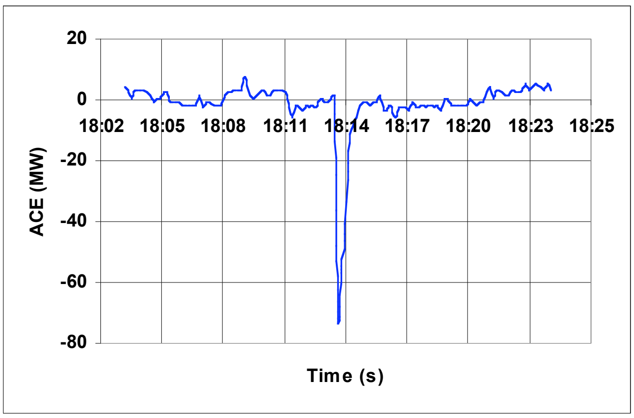

Fig. 5. ACE Behavior in Emergency Conditions

V. Conclusions

- In a general way, by means of the described procedure, there has been achieved a correct tuning of the CENACE's AGC, which has been demonstrated through the behavior of: the ACE, the frequency, the interchange and the response of the generation units under the control of the AGC
- It is necessary taking care of the parameters related to the filtering logic of the ACE and SCADA's signals, in order to avoiding over control on the generation units.
- The correct response of the AGC has been demonstrated during emergency conditions, since for a loss of 72 MW of generation in the pick demand period, the nominal frequency was recovered in less than 50 seconds.
- The state estimator, during a power system splitting in multiple islands, provided correctly to the AGC the information necessary for the operation in these conditions and the AGC supported the nominal frequency in the islands and the net interchange in the electrical interconnection with Colombia.
- It is recommended that the AGCs of both interconnected control areas have the same reference for frequency and interchange; for this purpose an ICCP link between Ecuadorian and Colombian control centers is used.

VI. References

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