

# Synchronous Compensators: Models Verified by Tests of Automatic Voltage Regulator, Reactive Power Control, and Voltage Joint Control

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**Abstract**—This paper presents models verified by tests of the excitation control systems (ECSs) of six large synchronous compensators (SCs) rated  $+125/-120$  MVar.

These equipments for grid voltage control are placed in the substation Ezeiza of 500 kV belonging to the Interconnected Argentine System (SADI in Spanish). The substation Ezeiza is located in the SADI load center.

Each SC has an ECS integrated by an automatic voltage regulator (AVR) with several limiters and a reactive power control (RPC). ECSs are governed by a single voltage joint control (VJC) to control the voltage at a 500-kV bus bar.

The ECS is UNITROL F from ABB and, the VJC is implemented in a programmable logic controller (PLC).

The AVR, RPC, and VJC models are presented. These models were predefined with information furnished by the manufacturer.

Then, these models were validated by tests. Test records and their simulations with the proposed model are also presented.

Described models have been incorporated to the database of dynamic models used for stability studies in the SADI.

**Index Terms**—Control system, excitation systems, limiters, modeling, reactive power control (RPC), testing, voltage control.

## I. INTRODUCTION

SEVERAL tests were made at synchronous compensators (SCs) plant during the commissioning of a new excitation control systems (ECSs). These tests were made to verify all the models involved and their adjustments.

The SCs are a 3901/01/660 type from General Electric, rated 13.8 kV and  $+125/-120$  MVar. Each SC has a shaft mounted exciter 3901/01/340 type from General Electric used as a driving motor for startup.

Fig. 1 shows the substation Ezeiza where the SCs are placed. Each pair of SCs is connected to one of the two secondaries of a transformer rated 132/13.8/13.8 kV and 250/250/250 MVA with Yd1/Yd1 connection and with individual on-load tap. Each primary of these three transformers is connected to the tertiary of a transformer rated 500/220/132 kV and 800/800/350 MVA with Yy0/Yd1 connection. The substation Ezeiza is interconnected to SADI grid through six 500-kV lines. Four of these six lines are 1600 km long, with series capacitor compensation,

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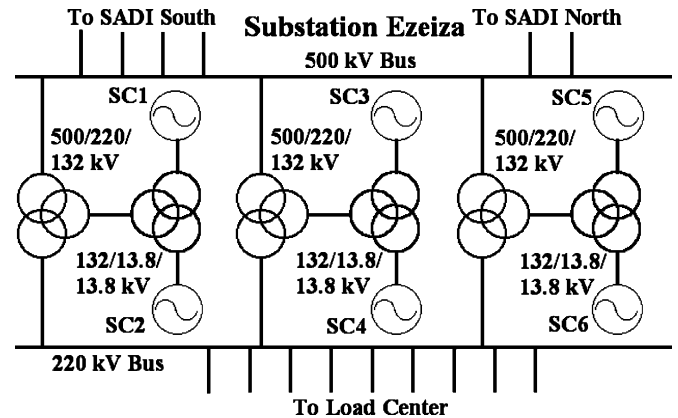


Fig. 1. Substation Ezeiza. SCs plant.

and carries power from Comahue electric area, located in the south SADI.

Comahue has several thermal and hydraulic power plants, with close to 10 000 MW of generation capability.

The last two of these six lines are connected to substation General Rodríguez, the connection point with the north SADI.

Substation Ezeiza is connected to the SADI load center (Buenos Aires city and surroundings) through several 220-kV lines. Then, the SCs plant control the 500-kV voltage at a critical node of SADI grid.

Each SC has a new ECS integrated by an automatic voltage regulator (AVR) and a reactive power control (RPC). The AVR has the following limiters: one over excitation limiter (OEL), two under excitation limiters (UEL), and a V/Hz limiter. The AVR also has compensation or droop to control a different voltage from the measured one.

The new voltage joint control (VJC) is implemented in a PLC.

Fig. 2 shows a simplified model of the six SCs at Ezeiza plant with the different control loop involved and their interconnection. Fig. 3 shows a simplified block diagram of one ECS shown in Fig. 2. This block is the same for each of the six SCs. The VJC set point (SP) for 500-kV bus voltage is fixed by plant operator. The VJC block generates the set point (QT SP) for each of the six RPCs with the error between its set point (SP) and its controlled voltage (500 kV). Then, steady-state control of 500-kV bus voltage is obtained through the VJC operation as a tertiary closed loop control that changes simultaneously all the RPCs set points.