Study Committee B4

PS3 - FACTS and Power Electronic (PE)

Paper 10781

125 Mvar STATCOM systems for oscillation damping and supporting HVDC-LCC reactive power unbalance

Cosimo PISANI, Francesco PALONE, Giorgio GIANNUZZI, Lorenzo AVELLINO, Luca BUONO, Benedetto ALUISIO
Terna S.p.A.

Motivation

- The decommissioning process of some large coal-fired power plants now prompts the need for new and more better performing devices for voltage control.
- In addition to high inertia synchronous condensers/flywheel systems, Terna started in 2020 a project aiming at introducing STATCOMs in the Italian 400 kV transmission network, for the first time.

Figure 1–STATCOM installations planned and currently connected HVDC-LCC to the Italian network.

Method/Approach

- A multi-vendor approach was adopted for STATCOM project, so that the STATCOMs will be manufactured by both local and international manufacturers.
- Terna adopted its unification paradigm, aiming at a standard design for all STATCOMs, at a better spare parts management, in order also to reduce both commissioning schedule and overall costs.
- To reduce the obsolescence risk, Terna imposed the use of the art Modular Multilevel Converter technology, using full bridge sub-modules.

Objects of investigation

- The paper aim to describe the main characteristics of STATCOM projects; the project includes the installation of **5 STATCOM**, each with a **± 125 Mvar rating**.

Experimental setup & test results

- The first three systems will be installed in the 400 kV Latina, Villanova and Galatina substations, in order to mitigate the reactive power exchange between the HVDC converter stations and the 400 kV network (particularly upon filter banks switching manoeuvres) and to damp possible low frequency voltage oscillations (Power Oscillation Damping – POD).

Discussion

- Although a multi-vendor approach was adopted for STATCOM project, Terna adopted its unification paradigm (the same rated converter voltage, same capability and main spare parts such as power transformer).
- The preliminary STATCOM capability for each supplier was evaluated by Terna according to current and voltage constraints of the main equipment, to prove the expected performances.
- Converter type tests have been performed by all supplier.
- The first three systems are still in construction in the 400 kV Latina, Villanova and Galatina substations.
- Real dynamic performances of Terna STATCOM projects will be evaluated during site commissioning.

Conclusion

- STATCOM is one of the **key technologies** considered by TERNA to face out the future energy scenarios, characterized by the large-scale integration of renewable energy sources;
- STATCOMs aim to **mitigate the risk of commutation failure** in the operating LCC-HVDC in weak AC grids;
- STATCOMs guarantee **voltage support** to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, **improve the transient stability margins** and to **damp out the system oscillations** due to these disturbances.

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TECHNICAL CHARACTERISTICS

- **Unification paradigm** (i.e. same characteristics of main equipment and power transformer for any STATCOM site) in order to reduce the Mean Time To Repair (MTTR), overall costs and commissioning procedures;
- **125 MVA 380 kV/35 kV Step-Up transformer**, with wye/delta winding connections and 12.5% short circuit impedance;
- **35 kV/ 0.4 kV 650 kVA Biberon Transformer** connected at the Medium Voltage (MV) to supply auxiliary system;
- **diesel generator** installed on Low Voltage (LV) side to guarantee a safe outage of STATCOM in case of blackout or trip of High Voltage (HV) circuit breaker;
- **three phase pre-charge resistors** installed in series between secondary winding and converter valves.

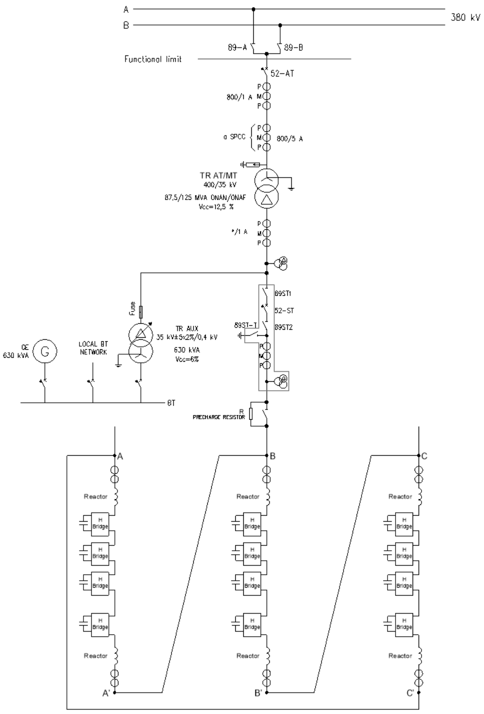

Figure 2–STATCOM single line diagram.

QV CAPABILITY

- A preliminary STATCOM capability for each supplier was evaluated by Terna according to current and voltage constraints of the main equipment:
  - $V_{C\text{-}MAX}$, $V_{C\text{-}MIN}$ - valve voltage constraints;
  - $I_{C\text{-}MAX}$ - valve currents constraint;
  - $V_{TR\text{-}MAX}$ - transformer voltage constraints.

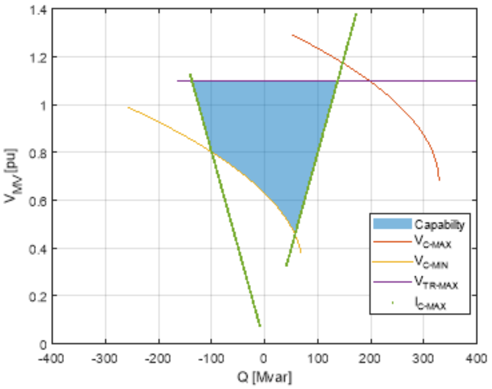

Figure 3–Expected Terna STATCOM capability seen on the secondary winding of power transformer.

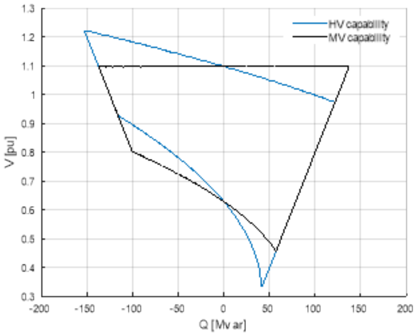

Figure 4–Comparison between the expected Terna STATCOM capability seen on the secondary winding (black) in per unit of 35 kV and on the primary winding (blue) in per unit of 400 kV.

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SITE CONSTRAINTS

- The substations presented **limited available space** and, furthermore, possible extensions of existing substation were not considered feasible;
- **Compact hybrid switchgear equipment** was adopted to reduce the footprint related to the MV air insulating equipment.
- Valve hall and control system will be installed inside **standard ISO containers** (three containers for each phase unit of converter and one container for control system)
- **Delta connection of phase unit** is realized outside the containers; therefore, converter terminals are connected to two wall-bushings per containers.
- The expected footprint of valve hall and control system is about **30 m × 20 m.**

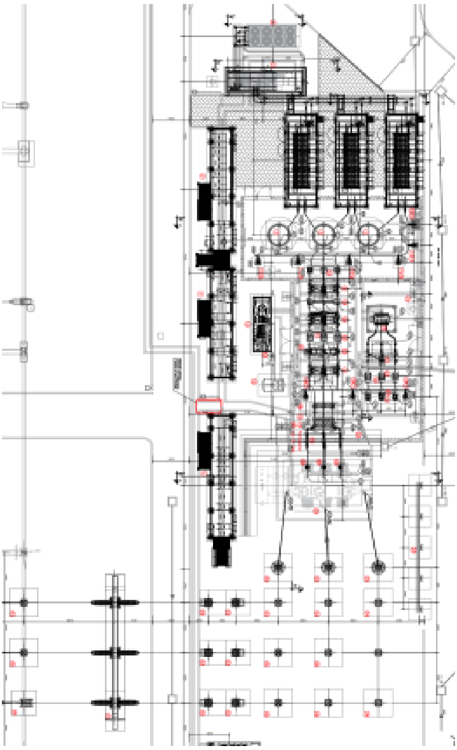

Figure 5 – Shelter solution (Latina STATCOM project).

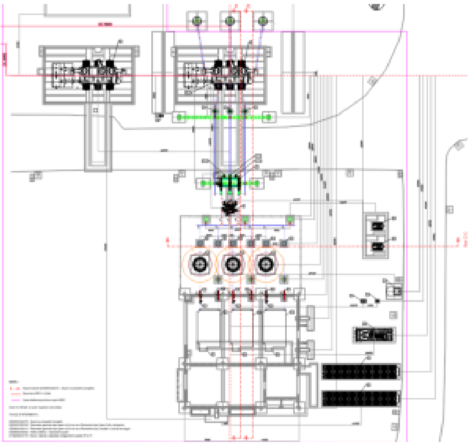

Figure 6 – Building solution (Galatina STATCOM project).

POWER OSCILLATION DAMPING

The POD is mainly applied to low-frequency electromechanical oscillations can be classified into two main categories:

- local (typically 0.7–2 Hz)
- interarea (0.1–0.7 Hz).

Oscillations are inherent to the synchronous generators and their rotors can swing either with or against the rotors of the other machines in the system

In the system STATCOMs achieve advanced power control and are typically installed for voltage regulation in transmission lines through proportional integral (PI) control. The POD controller is designed to produce an electrical torque in phase with the speed deviation according to the phase compensation method.

The speed deviation Δω is considered as the input to the damping controller, as in the figure below.

Figure 7–Power Oscillation Damping controller.