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Use of shunt reactors for smart voltage control in EHV/HV grid

4-05

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TSO MISSION

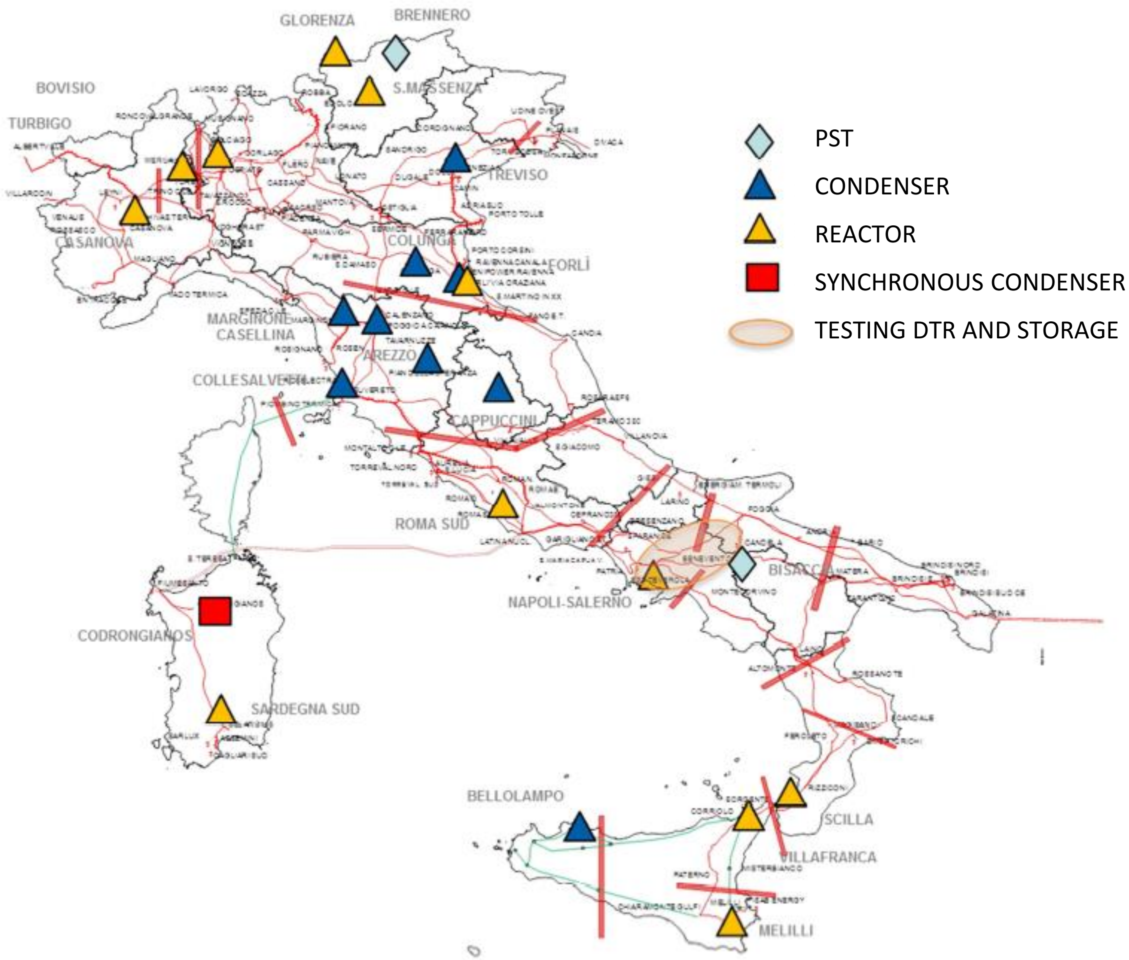
Make the electric transmission network

- flexible, in different operating conditions, that responds promptly to the needs of safety, reliability and efficiency of the electrical system
- dynamic, able to evolve quickly and efficiently in scenarios that change suddenly
- favoring as much as possible the integration of the increasing production from renewable sources

Smart transmission solutions

- Installation of Phase Shifting Transformers
- Installation of Synchronous Condersers
- Installation of Capacitors and Reactors
- Use of high-capacity conductors and Dynamic Thermal Rating- DTR
- Testing of distributed storage systems

Smart transmission solutions



source Terna NDP 2015

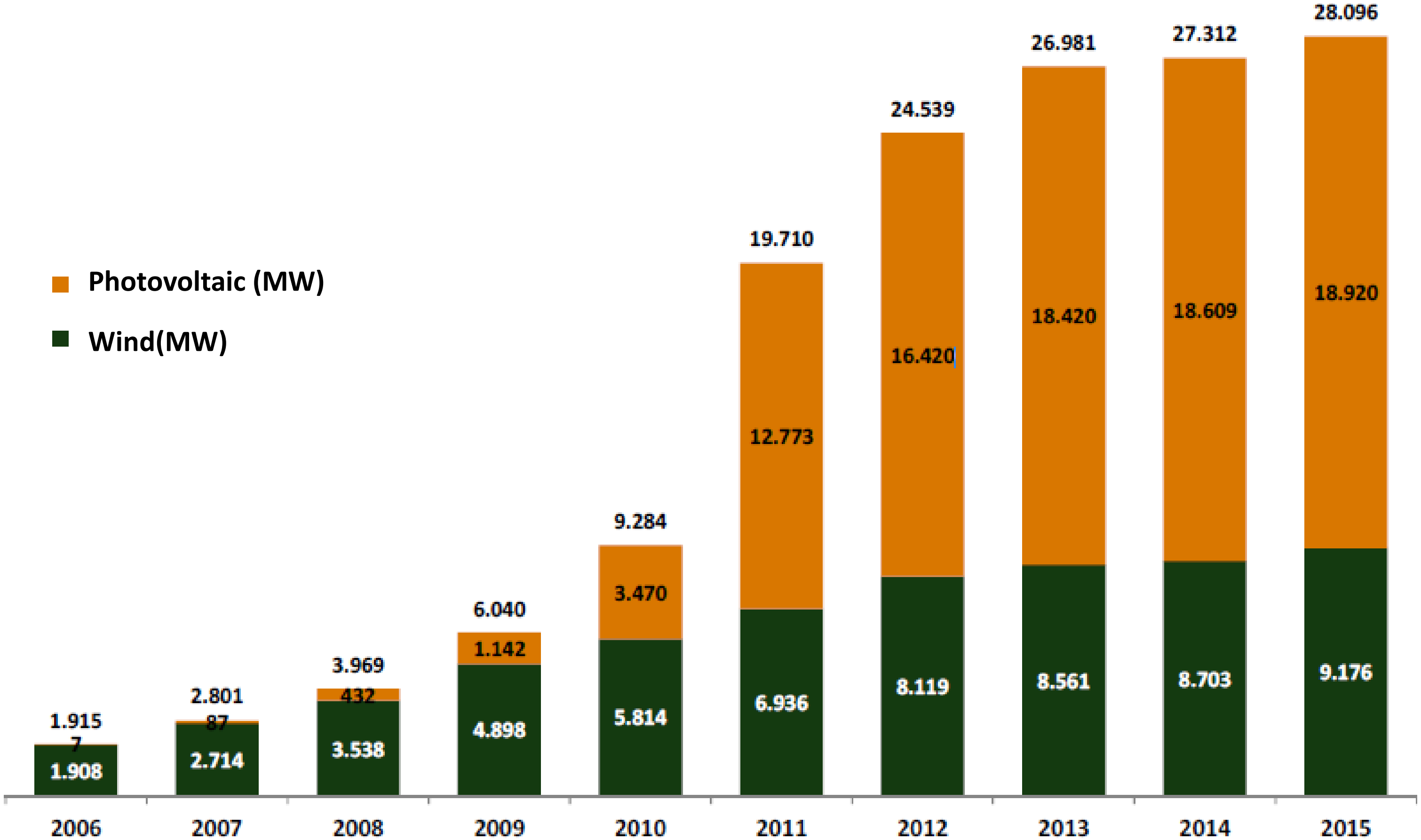
Smart transmission solutions

- Reduced environmental impact (as they allow to maximize the use of existing assets) and times and implementation costs lower than those required for the realization of new network infrastructure (lines and stations in high voltage)
- Great benefits in terms of increased levels of security and stability of the electrical system associated with the planned solutions have been confirmed (in terms of localization and installation priority) by simulations and sensitivity analyzes carried out on short - medium term scenarios

Reactive power need

- In general correct management of the power system requires that, in addition to an adequate supply of active power generation, it is also necessary settle a sufficient margin of available reactive power
- In recent years security problems of electrical system highlighted the need of installation of new reactive power of inductive type (reactor)

Renewable energy development



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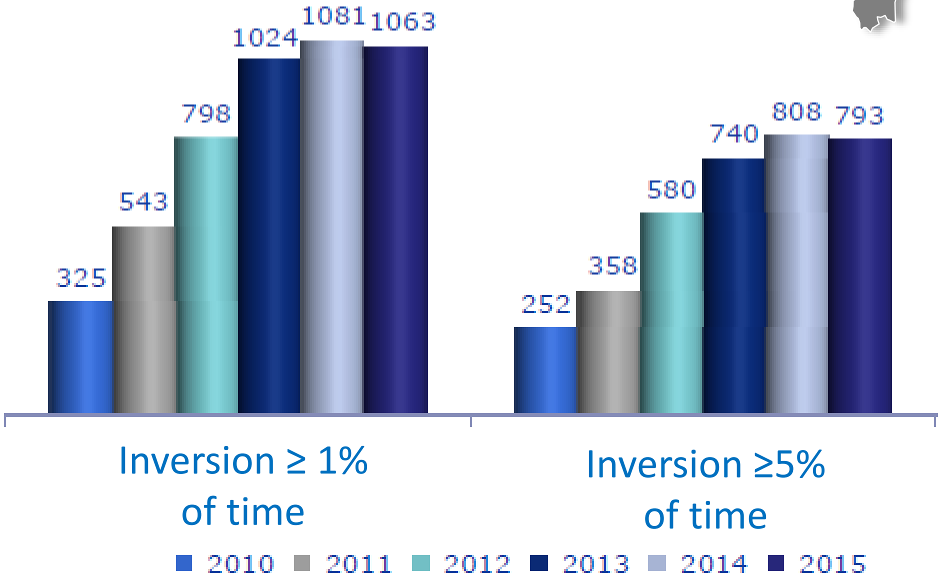
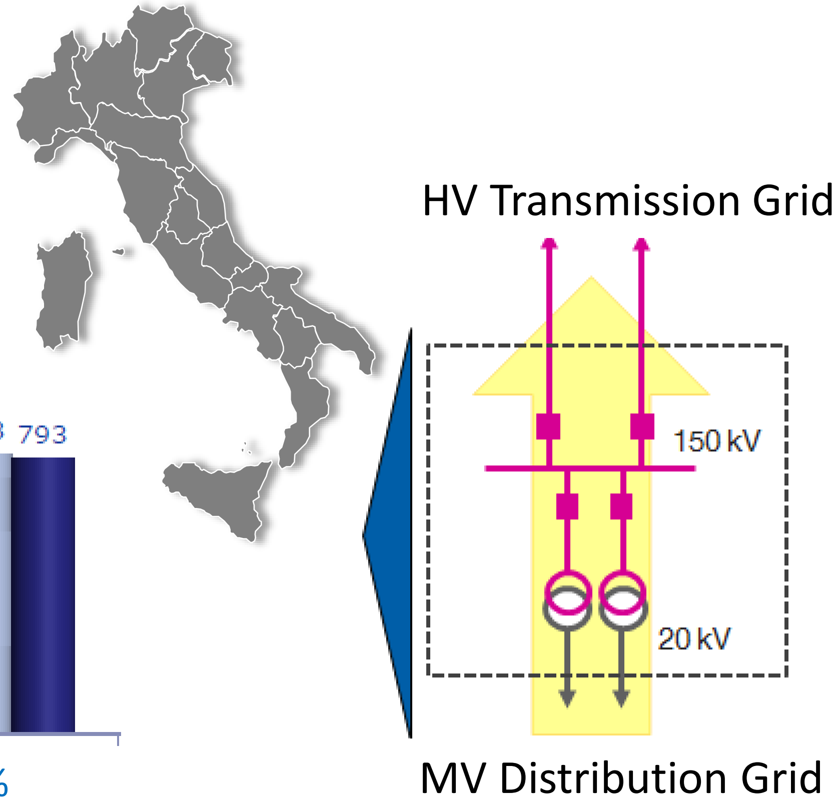
Change in exercise paradigma





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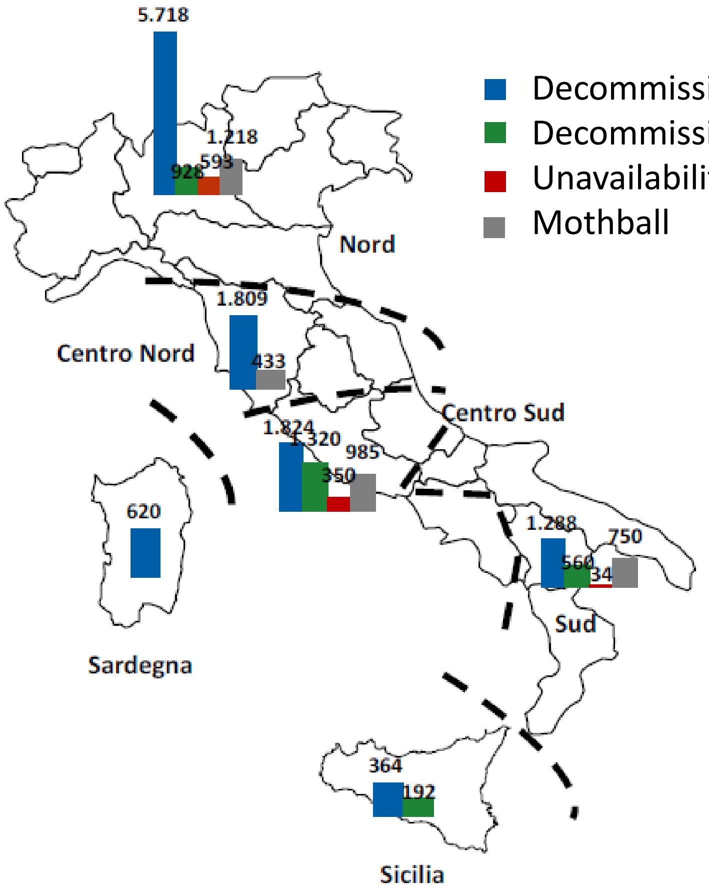
Decommissioning thermal power plant



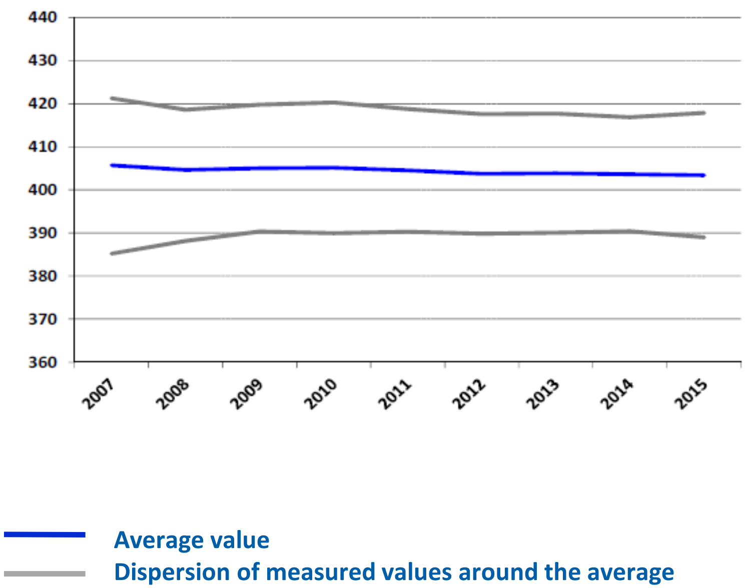
Decommissioning, unavailability, mothball thermal power plant 2012-2015

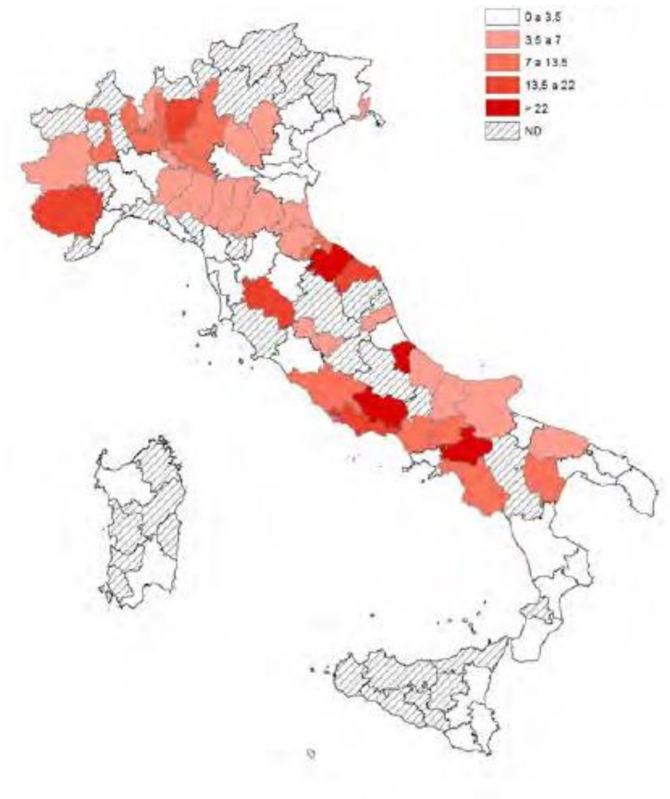
source Terna NDP 2016

Voltage quality on primary network

More critical areas

Voltage Range in 400kV nodes 2007-2015





Territorial voltage distribution on 400 kV grid
Time percentile (%) with voltage >410 kV july 2014-june 2015

source Terna NDP 2016

Shunt reactor choice

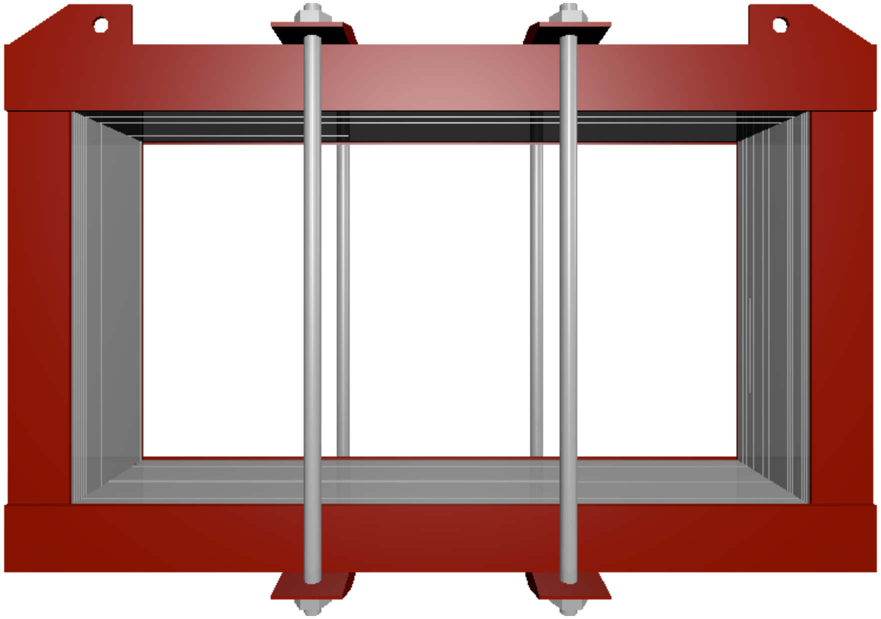
- In order to allow, even in off peak hours, an exercise more meshed of the EHV/HV network it is planned to install new reactors banks to the busbars of existing substations in many critical node of the grid
- With the installation of new reactors on the transmission grid, even in the minimum annual demand, voltage values remain below the maximum threshold allowed by the network code with a sufficient margin of safety
- In this contest shunt reactors are flexible devices capable of absorbing reactive power that can be employed to manage this hazardous issue, with the aim of increasing the efficiency and the safety of the network to the maximum

Shunt reactor choice

- Most common technologies are the gapped core and the coreless type technology
- The choice of the most suitable type of manufacturing depends on the final user specific requirements, especially concerning noise pressure level, power losses level, and reactance linearity
- In the following is presented an excursus on different reactor types and the technical solution adopded by Terna

Reactors constructive types

- Coreless type reactors
  - Reactor without a dedicated core

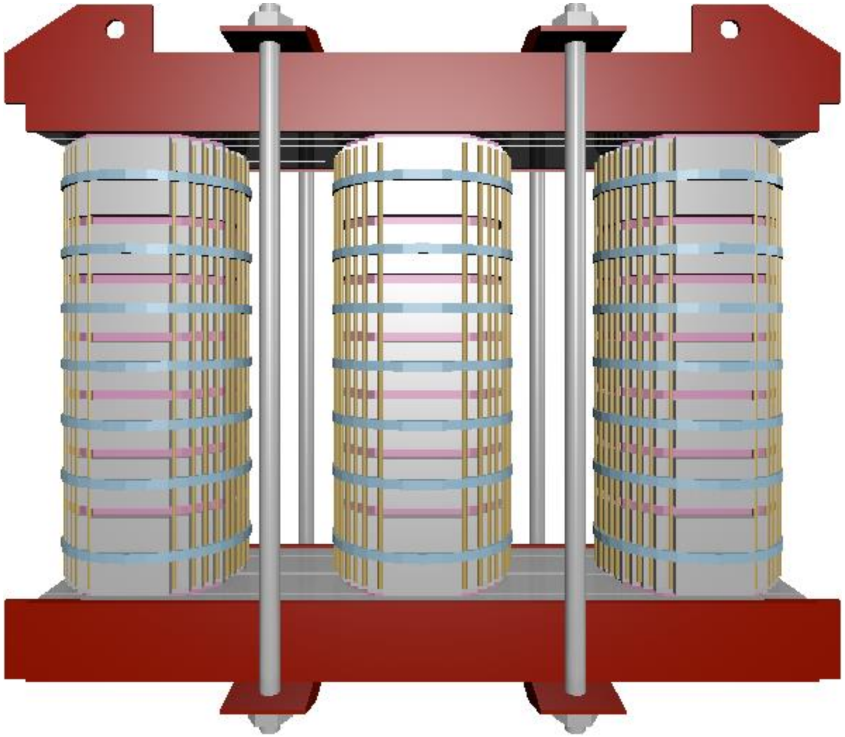


Reactors constructive types

- Coreless type reactors
  - Reactor without a dedicated core
  - Reactance due to turns
  - High linearity values
  - Low reactive power
  - Low values of reactance
- Common application
  - Industrial series reactors

Reactors constructive types

- Gapped type reactors
  - Reactor with a dedicated core
  - Reactance due to turns and gaps
  - Lower linearity values
  - High reactive power
  - High values of reactance



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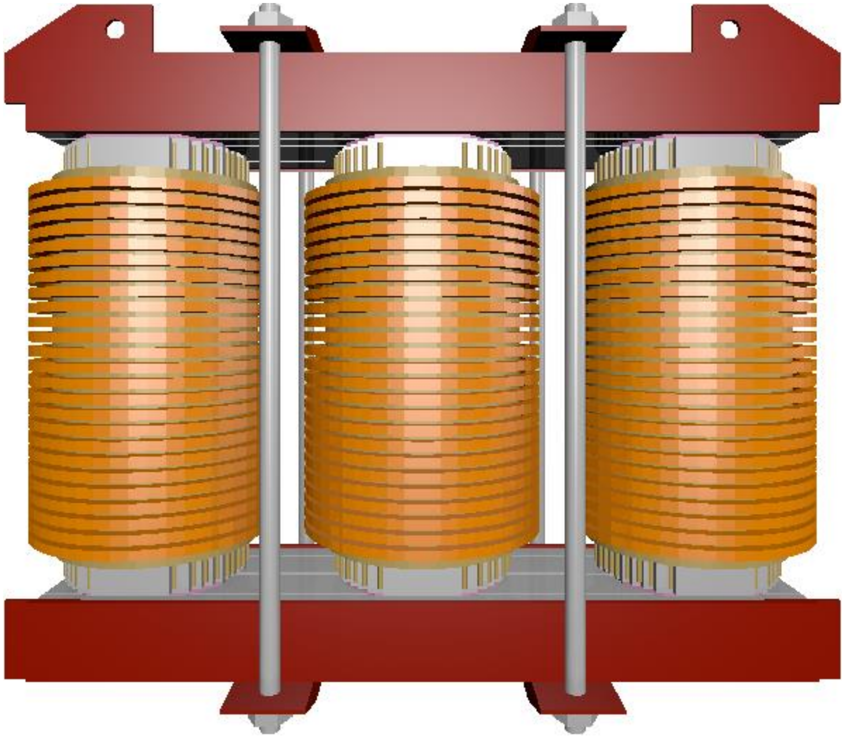
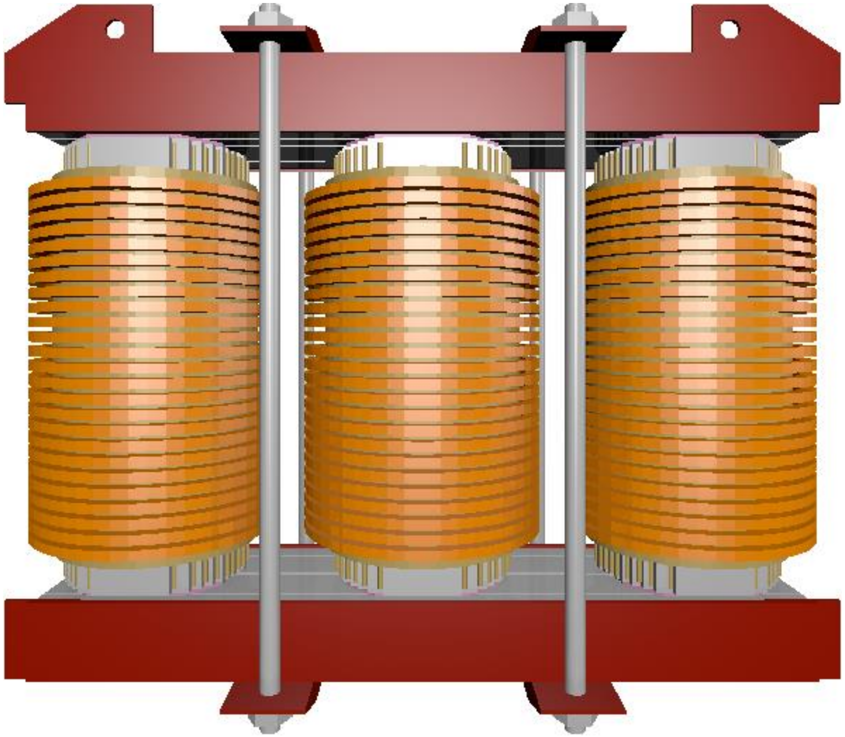
  - Industrial series reactors
  - Power shunt reactors



Reactors constructive types

- Gapped type reactors
  - Columns can have different arrangements
- Linear arrangement
  - Common solution

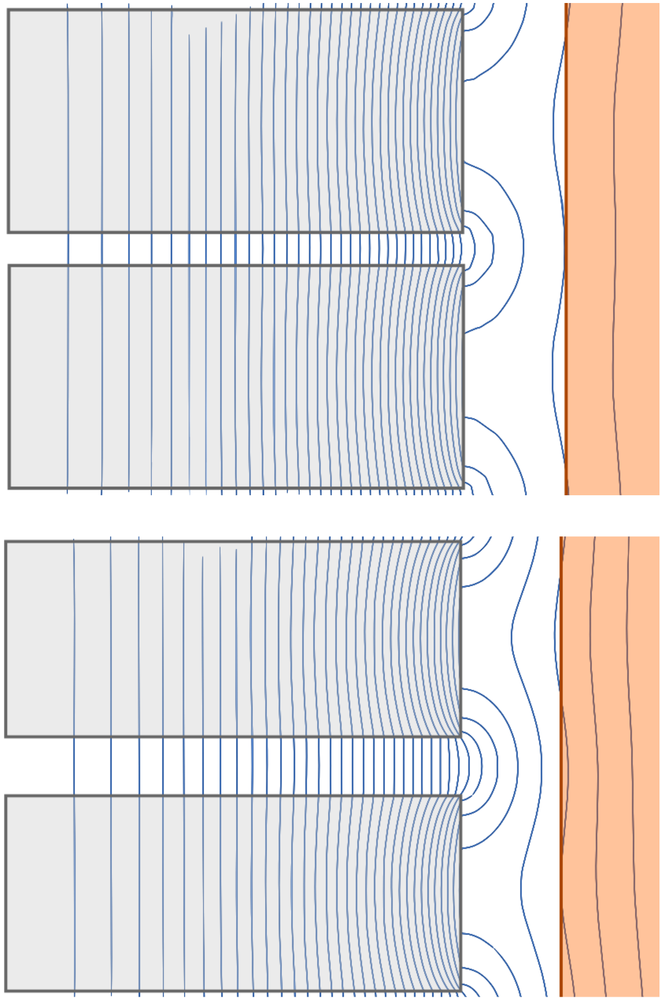


Reactors constructive types

- Gapped type reactors
  - Columns can have different arrangements
- Linear arrangement
  - Common solution
- Circular arrangement
  - Space saving solution
  - Noise sensitive

Influence of parameters on design solutions

- *Losses*
  - Peculiar stray flux distribution
    - Core losses
    - Winding stray losses
    - Flux distribution control is vital



Influence of parameters on design solutions

- *Losses*
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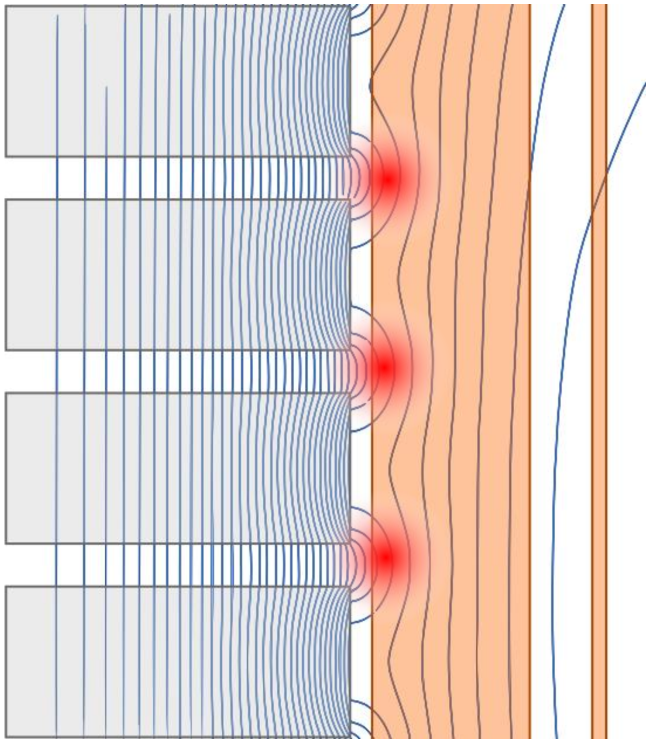
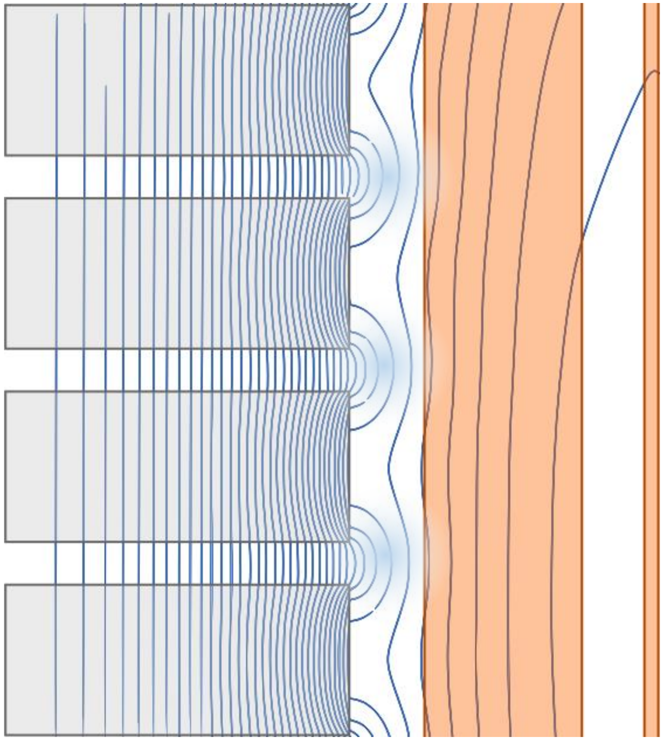
    - Winding stray losses
    - Flux distribution control is vital
  - Winding stray losses
    - Conductors shape
    - Distance from the core



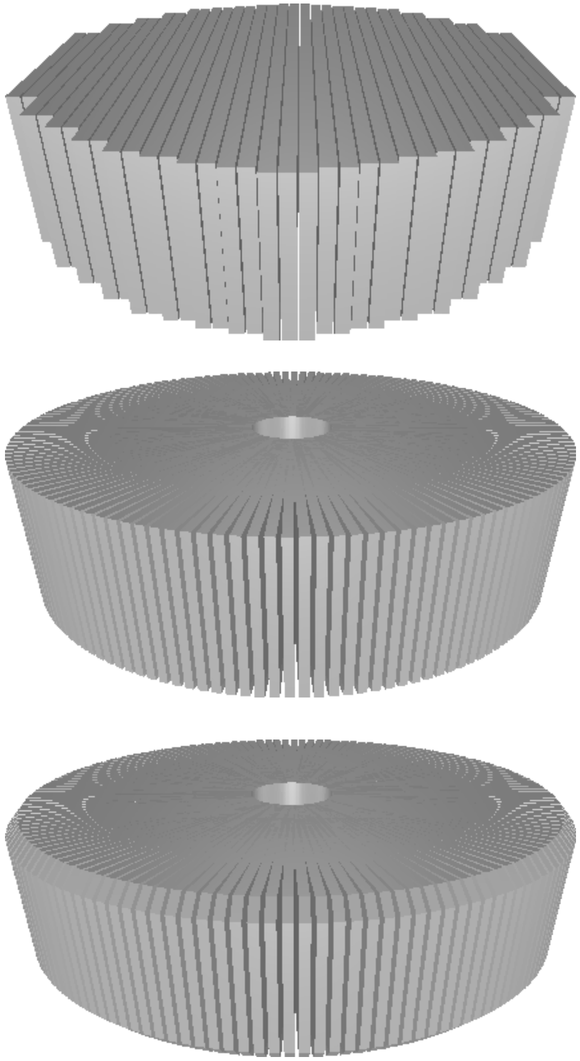
Influence of parameters on design solutions

- *Losses*
  - Peculiar stray flux distribution
    - Core losses
    - Winding stray losses
    - Flux distribution control is vital
  - Winding stray losses
    - Conductors shape
    - Distance from the core
    - Avoiding the most perturbed zones



Influence of parameters on design solutions

- *Losses*
  - Peculiar stray flux distribution
    - Core losses
    - Winding stray losses
    - Flux distribution control is vital
  - Core losses
    - Different sheets arrangements
    - Traditionally interwoven
    - Radially interwoven
    - Beveled edge



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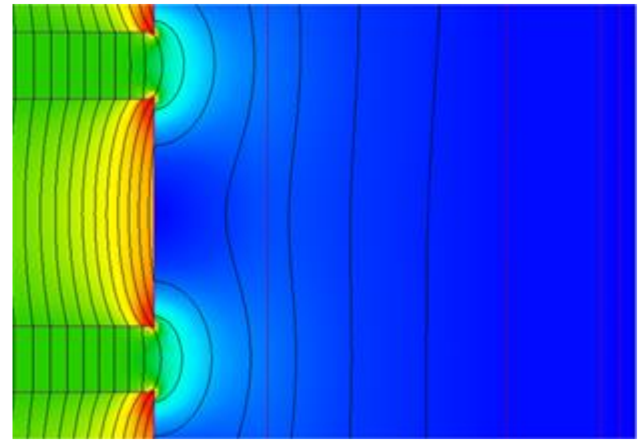
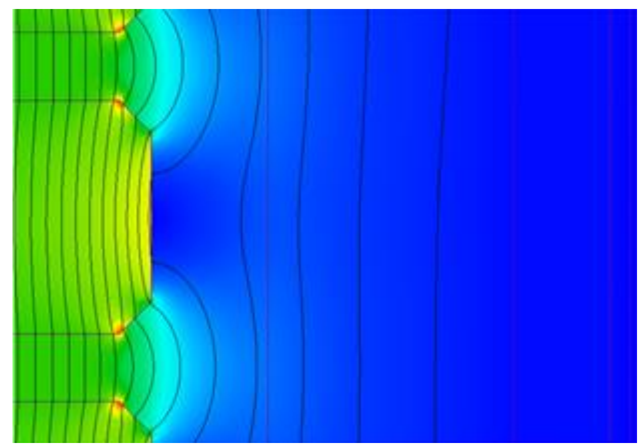
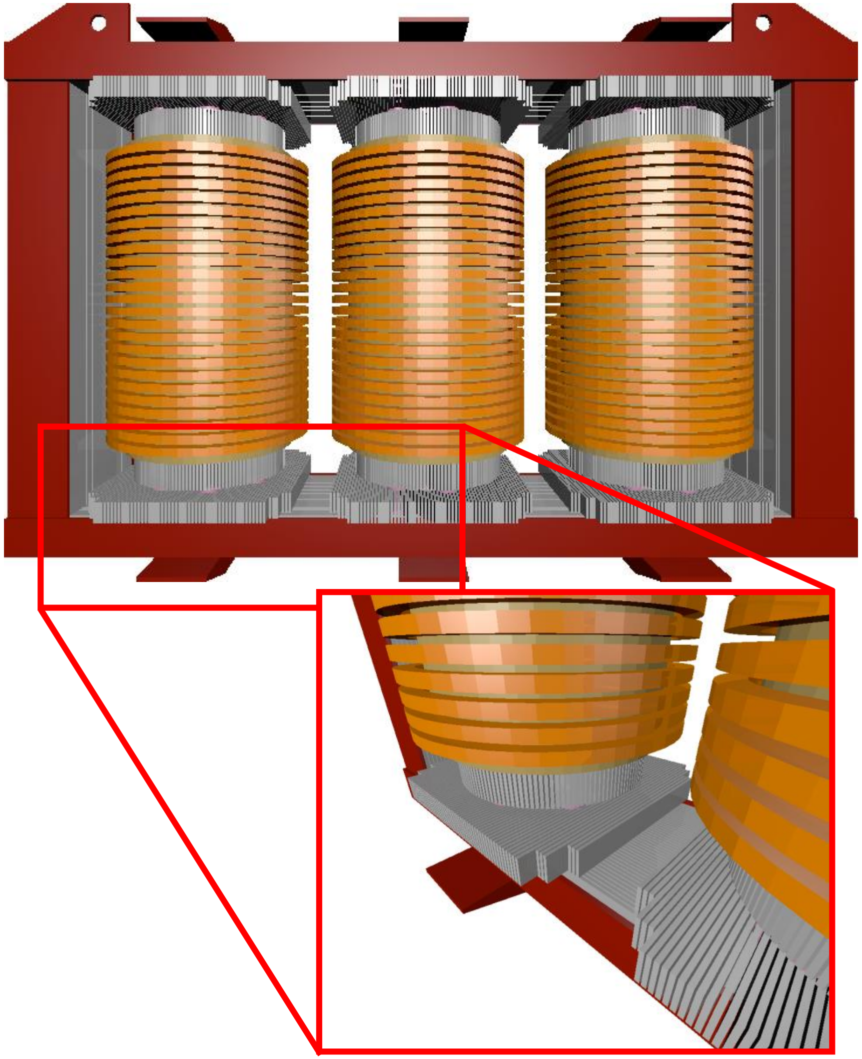




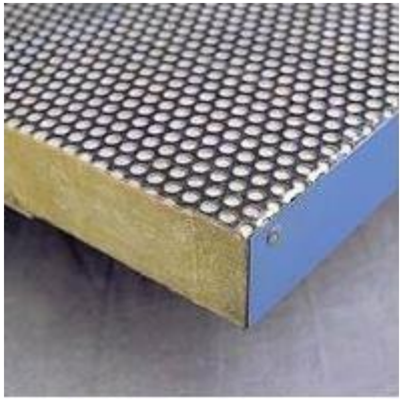
Influence of parameters on design solutions

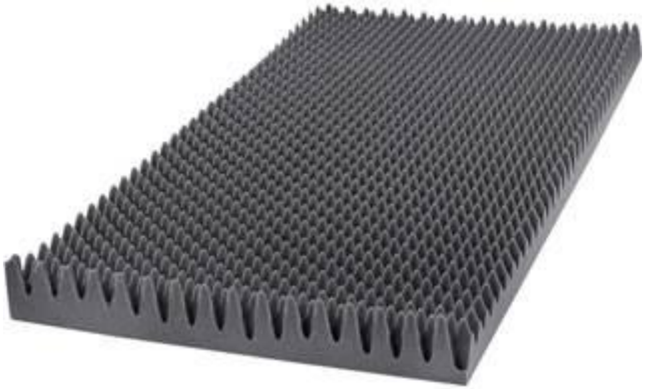
- *Losses*
  - Peculiar stray flux distribution
    - Core losses
    - Winding stray losses
    - Flux distribution control is vital
  - Core losses
    - Use of flux shields
    - Collect a higher amount of flux
    - Help the flux entering the core
    - Positive impact on stray losses



Influence of parameters on design solutions

- *Noise*
  - Due to active parts vibrating
    - Magnetic stresses
    - Magnetostriction
    - Gaps material moving under stress
  - Solutions
    - Careful core assembly
    - Reduce local flux thickening
    - Anti vibration devices
    - Tank thickening
    - Soundproof structures





Technical solutions adopted by Terna

- TERNA has chosen to install shunt reactors in the 400 kV and 230 kV systems of the grid for reactive compensation connected to the busbars of the substations in significant nodes of the grid

Rating datum	*Value*	
Core	gapped core	
insulating fluid	mineral oil	
linearity of the reactance	up to 150% U_r	
number of phases	single phase	
rated voltage	400 kV/√3	230 kV/√3
maximum permanent operating voltage	420 kV/√3	245 kV/√3
maximum temporary operating voltage	450 kV/√3	260 kV/√3
rated power	86 MVAr	60 MVAr
rated current	372 A	452 A
rated reactance	620 Ω	294 Ω
guaranteed losses	150 kW	120 kW
maximum sound power	88 dB(A)	85 dB(A)

Technical solutions adopted by Terna

- Gapped core design but with extended linearity to reduce the inrush current at the energization
- Single phase solution to permit a more efficient management of the spare units
- Regulation winding and an on-load tap changer, for a more flexible reactive management
- ONAN cooling system (radiators), pumps and fans not required for the loss level of these units
- Maximum vibration level limited at 100 μm peak-to-peak in order to guarantee a good design and quality of the magnetic core and to reduce the noise level