# Teknologisk Møteplass
# Pumpekraft

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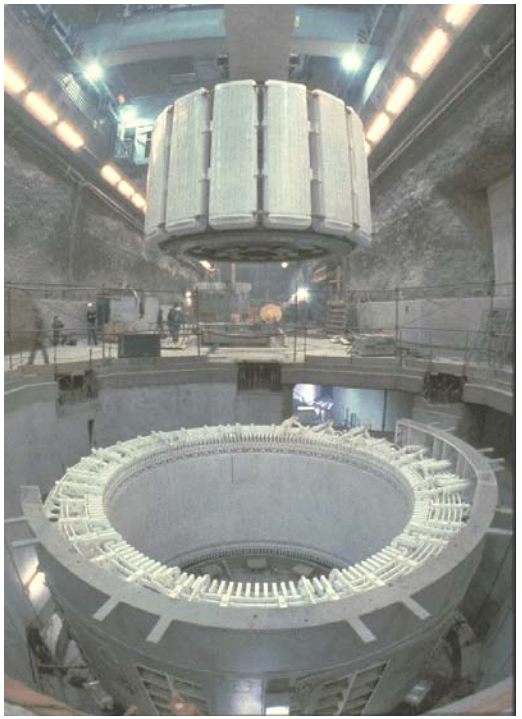
ALSTOM

## Design requirements for peak load units

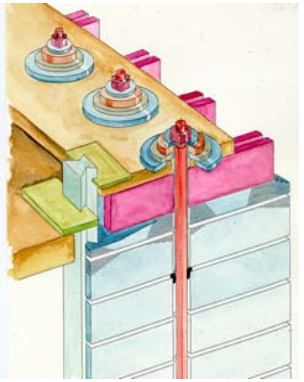
- Load and thermal cycles due to frequent starts and stops
- Bi directional speed for motor and generator modes
- High availability and reliability for peak load generator/motors
- Failure safe design concepts due to potential problems on the grid
- Maintenance free and redundancy in order to reduce outage time



# Experience

## Design features of peak load motor generators

- Structural design with oblique elements
- Stator core pressing system
- Micadur® insulation system
- Self pumping bearings
- Rim ventilation without electrical fans (self ventilated)

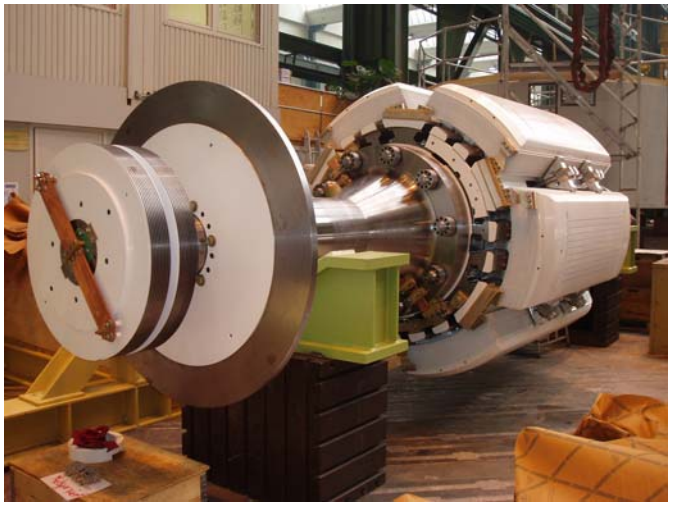


Designed for high availability and reliability

# Development Activities

## Challenges on high speed machines

- Cooling
  - Cooling of the coil between the support in the centre of the rotor
  - Temperature increase of the cooling air and hot spots on active parts
  - Ventilation losses
- Mechanical load
  - Pole claws, pole shoe and end plate
  - Pole coil
  - Inter-polar pole coil support
  - Rotor rim

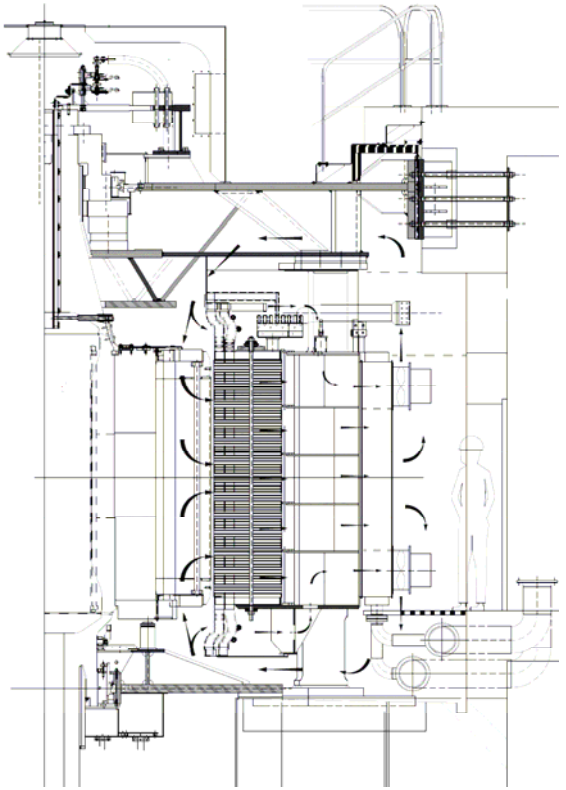


Conflicting situation between cooling and mechanical

# Development Activities

## Optimization and design limitations

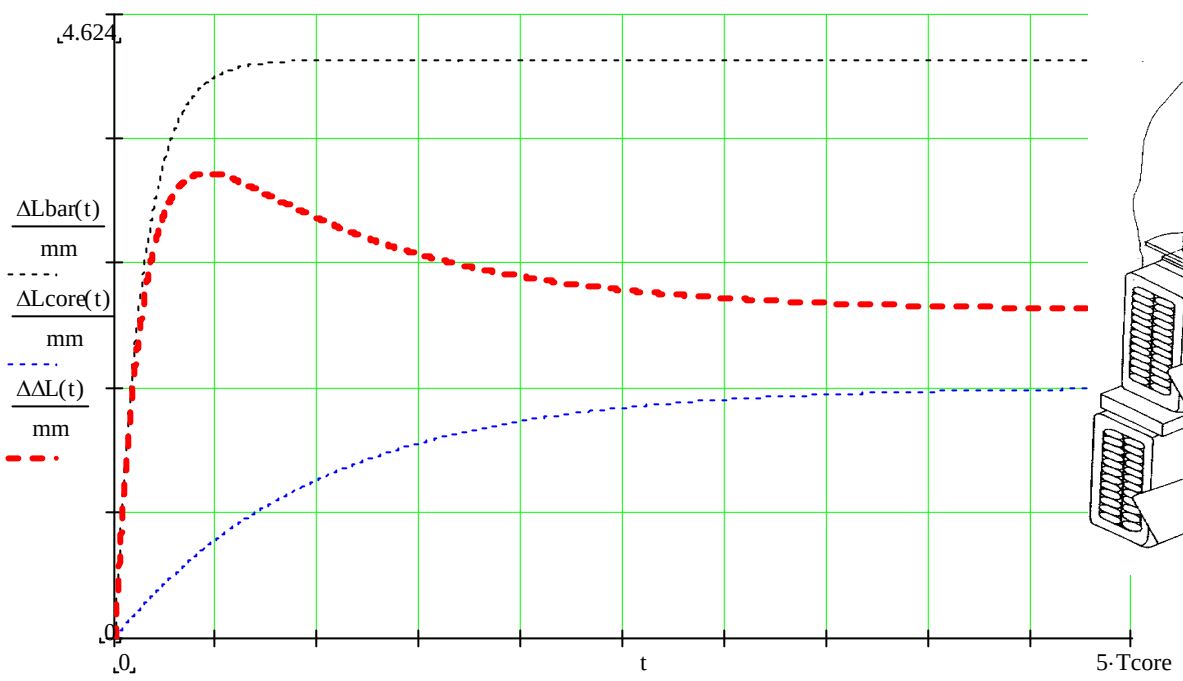
- Cooling and ventilation
  - ⇨ Efficiency
- Bearing design
  (losses, design guide lines, allocation of losses)
  - ⇨ Efficiency
- Mechanical design of pole coils and pole core
  - ⇨ Review design limitations and enable design optimization
- Critical bending speed
  (bearing distance, stiffness of structural design, runway speed, inertia requirement)
  - ⇨ Design optimization considering entire unit

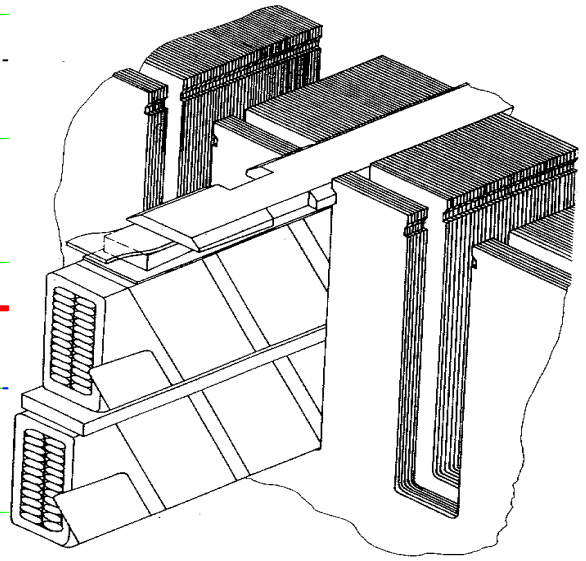


Afourer (190 MVA, 750 rpm)

# Development Activities

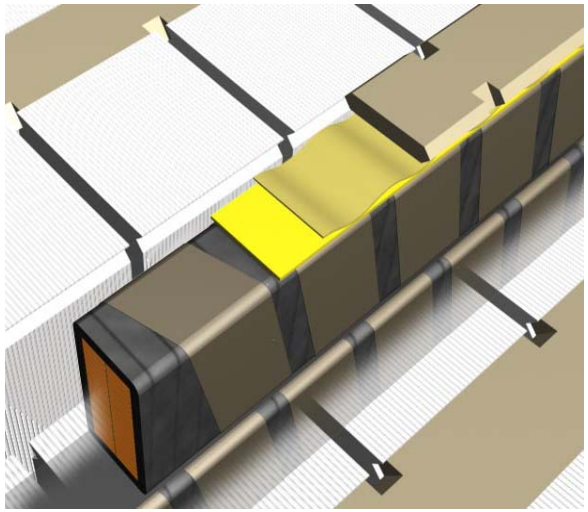
## Relative movements stator core – stator bar



## Stator winding technology

- Slot wedging system
  - Vibration of stator bars leads to partial discharges between the stator winding and the stator core
  - Deterioration of slot corona protection



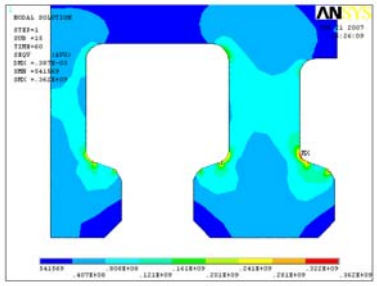
# Development Activities

## Thermal cycling of stator winding

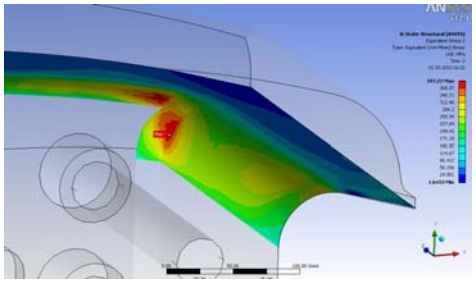
- Basic investigations
  - Bonding between insulation and copper
  - Failure mechanism and cycling criteria
  - Impact of manufacturing process parameters
  - Life endurance test after cycling

## Limitations and design space on poles

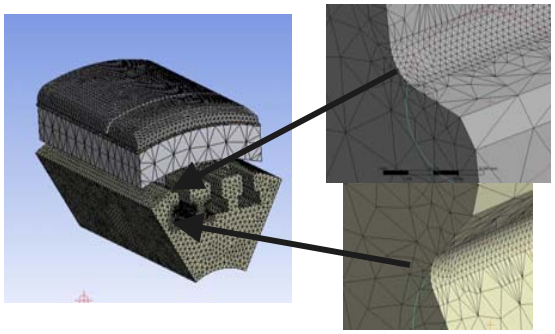
- 2D calculation of pole claws and 3D calculation for pole shoe on end plate (linear elastic calculation, analytical calculation model)
- 3D – calculation of complete pole (rim, pole, pole end plate, winding and insulation plate, linear elastic calculation)
- 3D – calculation of complete pole (rim, pole, pole end plate, winding and insulation plate, elastic plastic calculation)



2D FE calculation in combination with analytical calculation model



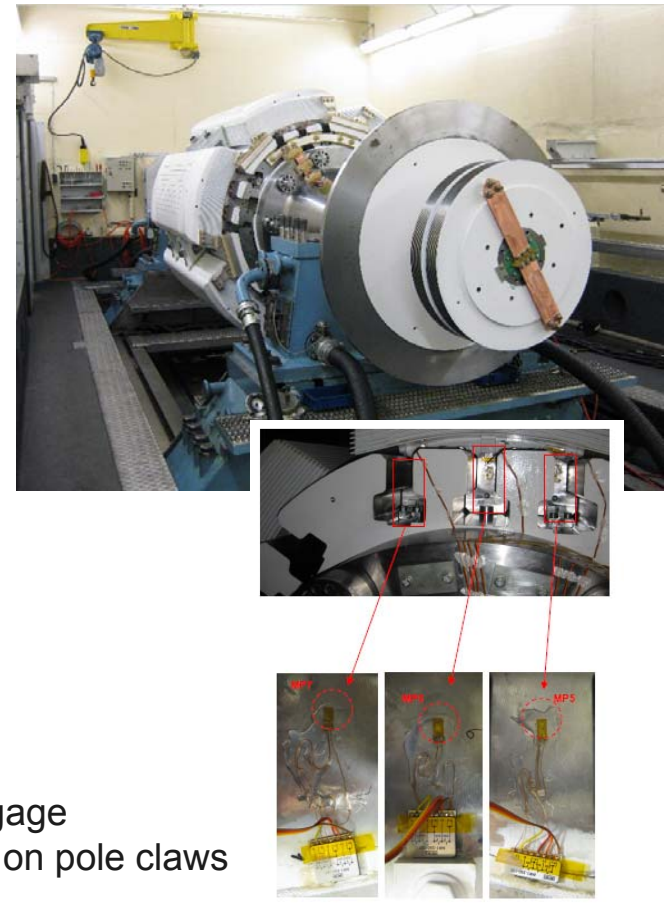
3D FE model of the pole shoe on end plate



3D FE calculation of entire pole and rim

## Limitations and design space on poles

- Main data
  - Power: 75 MW
  - Rated speed: 1000 rpm
  - Runaway 1510 rpm
  - Spin test 1650 rpm
  - Centrifugal load per pole 102’000 kN
- Purpose of measurements
  - Validation of calculated radial stress in pole claws and coil support
  - Control spin test



Picture: strain gage measurements on pole claws

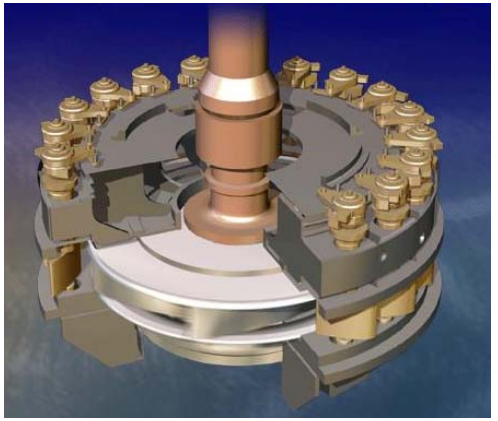
# Development Activities

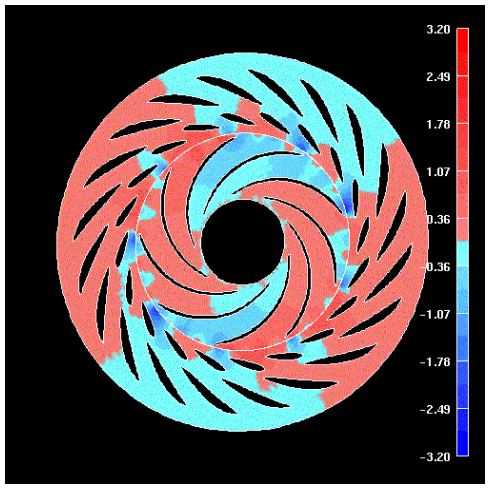
## High head Pump/Turbine design (single stage)

- Development and test of new hydraulic designs
  - Runner
  - Spiral case
  - Stay vane and guide vane
  - Draft tube

⇨ Improved performances of P/T

  - Higher efficiencies
  - Decreased level of pressure fluctuation

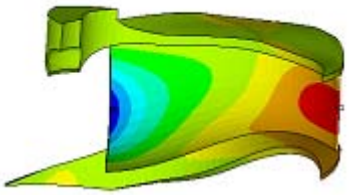




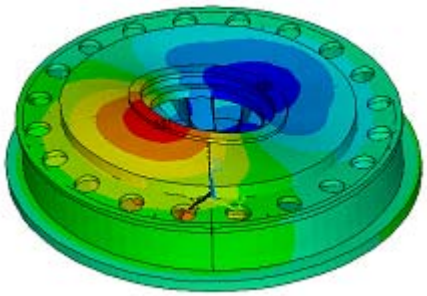
# Development Activities

## Mechanical design validation

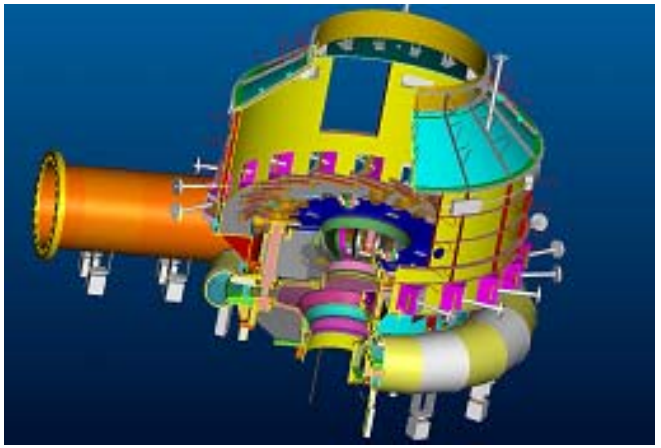
- Main components are checked by FEM calculations
  (Global analysis & specific analysis for local critical area)



- Directly connected to the Hydraulic design
- Performed using 3D software
- Design accuracy improved & time schedule reduced



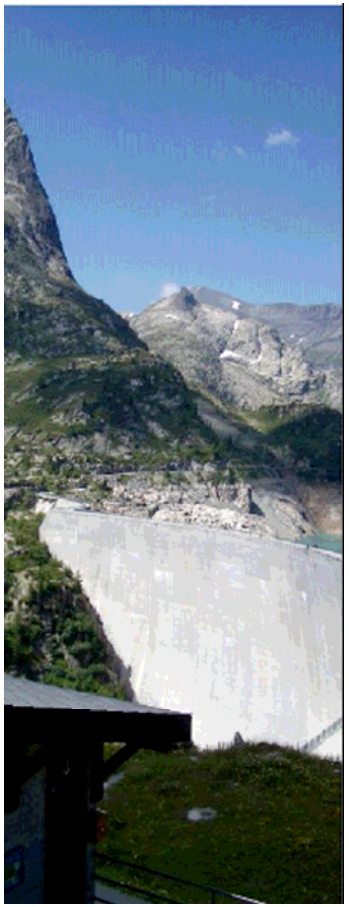
- Static, dynamic & fatigue analysis
  (Interaction between runner / guide vanes & head cover)



3D assembly of Baoquan

# Running variable speed projects

## Nant de Drance - Switzerland



- 4 x 155 MW Motor - Generators
- 428.6 ± 7 % rpm
- 250 – 395 m head range
- 11.4 Mio $m^3$ / 211.6 Mio $m^3$
- Commissioning 2015

# Running variable speed projects

## Linthal 2015 - Switzerland


- 4 x 250 MW Motor - Generators
- 500 ± 6 % rpm
- 560 – 724 m head range
- 25 Mio $m^3$ / 92 Mio $m^3$
- Commissioning 2015

# Running variable speed projects

Nant de Drance – ALPIQ/SBB
(Switzerland) 6 Units
157 MW – 307.7 m
428.6 rpm +/-7%
Runner Diameter 3.52 m
Model Test done (2008)
Under construction


Linthal 2015 – NOK
(Switzerland) 4 Units
255 MW – 613.2 m
500 rpm +/-6%
Runner Diameter 4.15 m
Model Test done (2009)
Under construction

# Conclusion

- Based on past projects and the success with recent designs ALSTOM has established broad experience in the whole range of PSP applications
- New operation condition for the generation units drives new requirements for the product specifications
- Alstom continuously investigates and improves design concepts considering all requirements for peak-load operation
- The combination of state of the art tools and feedback of experience enable further optimization of very high speed units and adjustable speed machines

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