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Study Committee A1

Rotating electrical machines

Paper 10834 (France)

Robust Design of Nuclear Turbine-Generators and AVRs for increased penetration of renewables and HVDC lines in transmission grids

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Motivation and objective

- Power system with high penetration level of renewable power sources usually connected to the grid through power electronic converters.
- Development of interconnections using HVDC transmission lines.
- High-power electronic based equipment connected close to conventional synchronous generators, including nuclear turbine-generators.
- Power-electronic converter control can destabilize torsional modes of nearby turbine-generators in weak grid conditions.
- TSOs, utilities working on screening and mitigation methods of risks of sub-synchronous torsional interactions (SSTI) between a power-electronic converters and turbine-generators.
- Poor damped torsional oscillations can cause torsional stresses at critical locations along the shaft-line, which may consume lifetime of the shaft-line or could in very worst-cases lead to damages.

- **The paper provides mitigation, protection methods and a possible improvement of the AVR control system.**

Mechanical design rules

- The torsional natural frequencies should be outside of the frequency range 90% to 110% of the nominal grid frequency (*fgrid*) and 180% to 220% of *fgrid*
- All natural torsion frequencies for the shaft-line shall have a minimum margin of +/-5% as compared with the frequency of the electrical network and its multiples

Protection strategies

A: Torsional Stress Relay (TSR), using shaft-line speed

B: Generator protection relay, using phase voltage and/or current measurements at the generator terminals

C: Model-based monitoring systems, using shaft-line speed

D: Combination of both electrical method (B) and model-based method (C)

E: Protective solutions integrated with the turbine controller, using shaft-line speed measurement

Improvement of the generator excitation control system

- Numerical notch filters on some of the resonance frequencies measured in the AVR in order to reduce the excitation source
- Active strategies, known as 'Supplementary Excitation Damping Control' (SEDC)
- SEDC designed to provide electrical damping to the first torsional mode (6.28 Hz) of a nuclear turbine-generator
- EMT simulations performed in small-signal conditions and large transients show the positive damping introduced by the SEDC loop for the concerned torsional frequency

Conclusion

- Specific shaft-line design rules and different protection systems are presented
- Based on a simplified test-system, the effectiveness of SEDC loop was demonstrated

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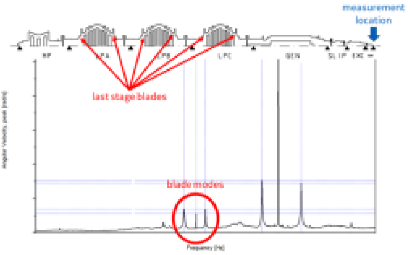
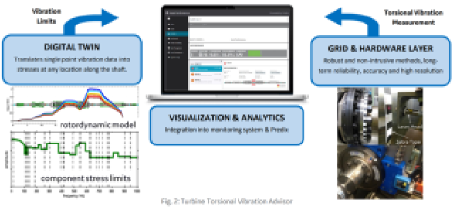
Mechanical model-based monitoring systems

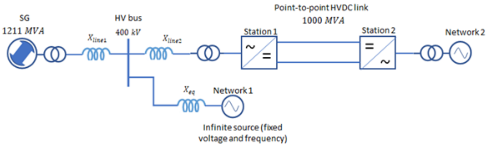
- Estimation of torsional vibrations at different locations along the shaft-line using accurate measurements and detailed rotor-dynamic model



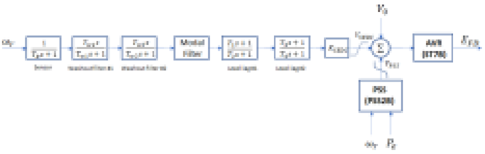


Case study: assessment of SEDC AVR control strategy

- A three branches simplified test system;
- EMT model including detailed model of turbine-generator and HVDC converter control

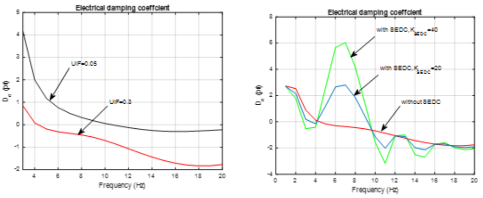


- Supplementary Excitation Damping Control (SEDC)=extension of the PSS concept used for torsional frequency oscillation damping
- A damping reference based on measured rotational speed is added to the AVR

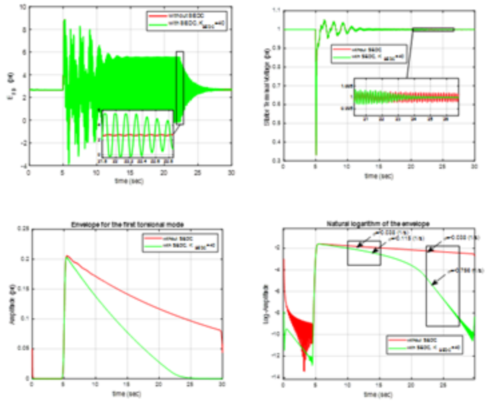


Simulations results

- In weak grid conditions (UIF=0.3), the electrical damping introduced by the system is negative ⇒reduction of the global damping of torsional modes.
- SEDC loop allows introducing a positive damping for the first torsional mode of the turbine-generator.



- SG controllers (AVR, PSS, SEDC) performances evaluated in large disturbance (short-circuit fault);



- SEDC loop does not affect the stator voltage recovery after the fault clearing
- SEDC provides damping for the first torsional mode in large transients when the AVR output reaches the specified limits

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