C4 POWER SYSTEM TECHNICAL PERFORMANCE

PS3 - Challenges and Advances in Power System Dynamics

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Sub-synchronous Resonance Monitoring based on Real Time Data

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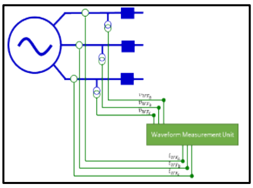
Motivation

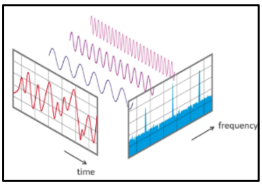
- A pilot to analyze the sub-synchronous resonance (SSR) phenomenon during real-time operation is required.
- A methodology based on waveform measurements and the Frequency Scanning technique can calculate electrical damping.

Methodology

- The first step is to define a measurement scheme that allows this goal to be carried out.



Connection scheme



Visual example of the expected spectral decomposition

- It is used spectral decomposition through Fast Fourier Transform for each waveform of voltage and current.

$$v_{WF_{ph}} = \sum_{i=1}^{N} \vec{v}_{ph_{f_i}} \mid ph = a,\ b,\ c \qquad (1)$$

$$i_{WF_{ph}} = \sum_{i=1}^{N} \vec{i}_{ph_{f_i}} \mid ph = a,\ b,\ c \qquad (2)$$

- Then, for each sample resulting at each frequency the impedance of each phase observed by the generator towards the network can be calculated in (3).

$$\vec{Z}_{ph_FWD_{f_i}} = \vec{v}_{ph_{f_i}} / \vec{i}_{ph_{f_i}} \qquad (3)$$

- The second part corresponds to calculate the impedance seen from the neutral point of the generator. The generator impedance is calculated in (4), (5) and (6).

$$\bar{Z}_{d(\omega)} = j\frac{\omega}{\omega_N}X_d * \frac{1+jT'_d\,(\omega-\omega_N)}{1+jT'_{d_o}\,(\omega-\omega_N)} * \frac{1+jT''_d\,(\omega-\omega_N)}{1+jT''_{d_o}\,(\omega-\omega_N)} + R_A \qquad (4)$$

$$\bar{Z}_{q(\omega)} = j\frac{\omega}{\omega_N}X_q * \frac{1+jT'_q\,(\omega-\omega_N)}{1+jT'_{q_o}\,(\omega-\omega_N)} * \frac{1+jT''_q\,(\omega-\omega_N)}{1+jT''_{q_o}\,(\omega-\omega_N)} + R_A \qquad (5)$$

$$\bar{Z}_{Gen(\omega)} = \frac{\bar{Z}_{d(\omega)} + \bar{Z}_{q(\omega)}}{2} \qquad (6)$$

- Then, total impedance is obtained in (7) and (8).

$$\bar{Z}_{f_i} = \bar{Z}_{Gen_{(\omega)}} + \bar{Z}_{ph_FWD_{f_i}} \qquad (7)$$

$$\bar{Z}_{f_i} = R_{fi} + jX_{fi} \qquad (8)$$

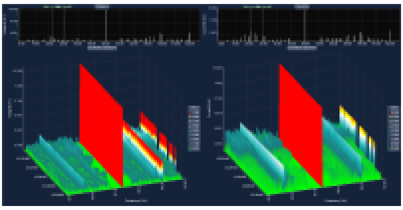
- Next step is to calculate the electrical damping for each torsional mode. As can be seen in the formula (9), electrical damping has sub-synchronous and super-synchronous conductance as input data, which explains the need to have measurements up to 120 Hz (in the case of 60 Hz power systems).

$$\sigma_{en} = \frac{1}{2}\left(1-\frac{f_0}{f_n}\right)\left(\frac{Q_{gN}^2}{4H_N}\right)\left[G_{sub,n} + \left(\frac{f_n+f_0}{f_n-f_0}\right) * G_{sup,n}\right] (rad/s) \qquad (9)$$

- As a last step, the mechanical damping is compared against the calculated electrical damping.

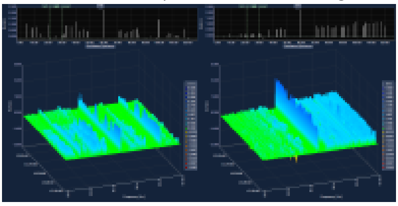
Monitoring Records

- Records have been obtained, as implemented by ELPROS and COES, in the WAProtector PDC software as part of the SSR Monitoring Pilot Project.
- Through the installation of PMU at the steam unit, the measurement of the frequency spectrum seen from the generation terminals of this unit is obtained.



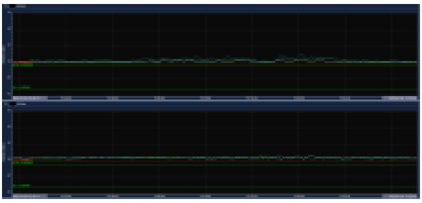
Frequency spectrum of phase B of a steam unit

- As a next step, the frequency of the last measured points is used, whereby the formulas (4), (5) and (6) are used to obtain the impedance seen from the generator.



Calculation of the impedance seen from the neutral of the generator, for phase B of a steam unit (historical record).

- The electrical damping is obtained (9). For this report we show the results for all day measurements of a steam turbine unit, which it has the mechanical frequency of the 1st torsional mode near 21.6 Hz and, in the second torsional mode, about 30 Hz of frequency.



Record of electrical damping of the phases of a steam unit

- In the case that there are positive values, it means that there is no exposure to the SSR phenomenon.
- However, in the event that it is more negative than the mechanical damping, it is necessary to carry out an inspection in the generating unit, in order to determine if there was damage during exposure to the SSR.

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