Experience with Hydro Generator Stator Noise due to Air Gap Harmonic Forcing.

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Stator core vibration has been an issue following hydro generator overhauls involving continuous stator core restacking and rewinds. Changing the number of slots, moving to a Roebel winding vs. multi-turn winding, and moving from segmented to continuous cores have resulted in stator pulsations at 120 Hz or high pitched noise at a discrete harmonic (multiple) of 120 Hz. In order to understand and eliminate this behavior in the design stage, the in-plane bending and extensional modes and natural frequencies of vibration of hydro generator stators over the range from 0 – 1200 Hz was investigated using finite element analysis and classical mechanics. This included a comparison between a segmented and continuously stacked stator as well. Though most stators can certainly be classified as "thin rings," results for the bending modes using finite element analysis and thin ring theory were found to diverge as the number of waves around the stator increased. It was clear to the investigator that the divergence was due to the fact that the shorter wavelengths at the frequencies of interest made the assumptions of thin ring theory invalid. Thus an alternate approach from classical mechanics using Timoshenko Beam formulation was employed. The Timoshenko formulation for beam vibration accounts for transverse shear deflection as well as rotatory inertia of the beam's mass due to the bending motion. However, though an improvement, even this did not reconcile the results satisfactorily. By observing the nodal positions, the writer was able to reconcile the results by introducing a new term to the Timoshenko formulation that approximated the effect of the offset mass of the stator teeth. This was applied to several cases of stators that have experienced elevated noise at harmonics of 120 Hz and found to predict troublesome frequencies more closely. The formulation used here was not rigorously derived but was based on physical reasoning. A literature search is ongoing and refinements are being pursued.

The paper will discuss briefly the source of air gap forcing frequencies. Assumptions regarding the calculation of stator natural frequencies will be explained; then comparison between thin ring theory and the Timoshenko formulation will be dealt with; then the reasoning behind the modification will be demonstrated, and results compared to previous known cases of elevated stator harmonic noise. The upper bounds of the suitability of these calculations will also be discussed.