Case History

High Shaft Vibration of a Synchronous Generator

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This case history describes the reduction of high shaft vibration of a synchronous generator with field balancing. Results from an unbalanced response analysis are used to explain the sensitivity of the generator to unbalance at the exciter.

The 40 Mw synchronous generator is driven by a gas turbine at 3,600 RPM. High shaft vibrations were measured with the proximity probes at the bearings during an acceptance test. Vibration levels were higher at the drive end (DE) bearing than at the non-drive end (NDE) bearing. The data are summarized in the Table. Field balancing was done using the least squares method to reduce the bearing vibration.

The generator has a cooling fan on both ends of the core; each was accessible for placing balance weights. The first trial weight, 3.8 oz at 315° opposite rotation from the key phasor, was located at the fan on the drive end. When the generator was re-started with the trial weight installed, vibration levels were higher than the baseline (no weights) shown in the Table. A single-plane balance calculation predicted a correction weight of 3.6 oz at 137°. Because the predicted residual vibration levels were not much lower than the baseline, another balance location was selected. Another balancing location was then selected.

The trial weight on the drive end fan was removed. A second trial weight (2.3 oz at 180°) was placed on the exciter, which is located on the non-drive end of the generator. Again, the vibration levels were higher than the baseline shown in the Table. A trial weight is a guess. However, a significant change in vibration amplitude or phase provides information useful in calculating influence coefficients. The single-plane calculation predicted a correction weight of 3.0 oz at 4°. The residual vibration levels with this correction weight were predicted to be much lower. When the correction weight of 3.0 oz at 4° was attached to the exciter, the vibration decreased to an acceptable level of less than 1.8 mils peak to peak (see the Table).

The data from the two trial weights were sufficient to carry out a two-plane balance calculation. The predicted weights were 2.1 oz at 248° on the drive-end fan and 3.2 oz at 359° on the exciter. The predicted residual vibration was similar to that predicted by the single-plane balance based on the trial weight on the exciter. The predicted correction weight for the exciter is almost the same with either the single-plane or two-plane

	DE X	DE Y	NDE X	NDE Y
Baseline (No Weights)	2.27 mils p-p @ 219°	1.09 mils p-p @ 6°	1.38 mils p-p @ 212°	0.82 mils p-p @ 44°
Drive End Fan 3.8 oz @ 315°	2.60 mils p-p @ 206°	1.34 mils p-p @ 1°	1.72 mils p-p @ 240°	1.41 mils p-p @ 58°
Exciter 2.3 oz @ 180°	3.70 mils p-p @ 215°	1.86 mils p-p @ 2°	2.77 mils p-p @ 219°	1.26 mils p-p @ 33°
Exciter 3.0 oz @ 4°	1.35 mils p-p @ 230°	0.60 mils p-p @ 6°	0.80 mils p-p @ 166°	0.51 mils p-p @ 79°

Summary of Measured Vibration from Generator Balance.

balance. The correction weight on the drive-end fan did not appear to be necessary and was not used.

An unbalanced response analysis was performed on the generator to determine why a balance weight on the exciter more effectively reduced vibration at the drive-end bearing than a weight placed on the drive-end fan. The correction weight was placed at a six-in. radius on the exciter so that the resulting unbalance was 18 in.-oz. This value was entered into the rotor-dynamic model. The calculated response at the bearings versus speed is shown in Figure 1 and Figure 2. The generator appeared to be operating 8% below the third critical speed of 3,900 RPM. The calculated response shape at 3,600 RPM (Figure 3) indicates that the non-drive end bearing is closer to a node than the drive-end bearing and would therefore be expected to have much lower vibration levels. The response shape also shows that the maximum vibration amplitude occurs at the exciter; it is thus the most sensitive location for unbalance.

Analytical results correlated well with the data obtained from the field balance and previous shop tests in which the generator was taken to speeds above 3,600 RPM. The calculated separation margin from the third critical speed is less than desired. A detailed lateral critical speed analysis in the design stage would have allowed modifications to the rotor and bearings to increase the separation margin to at least 15% and decrease the sensitivity to unbalance.

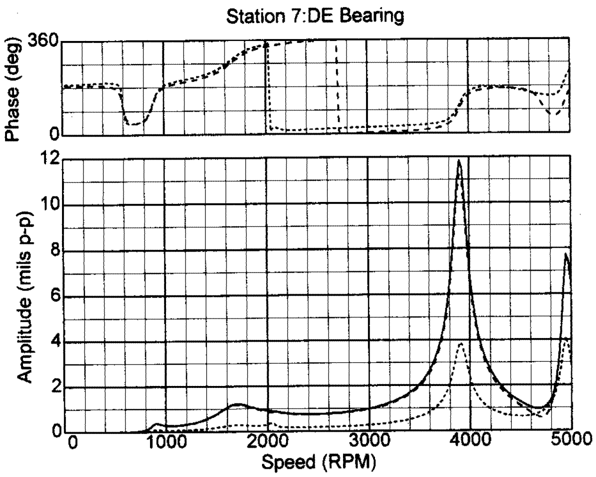

Figure 1. Calculated Unbalance Response at Drive-End Bearing.

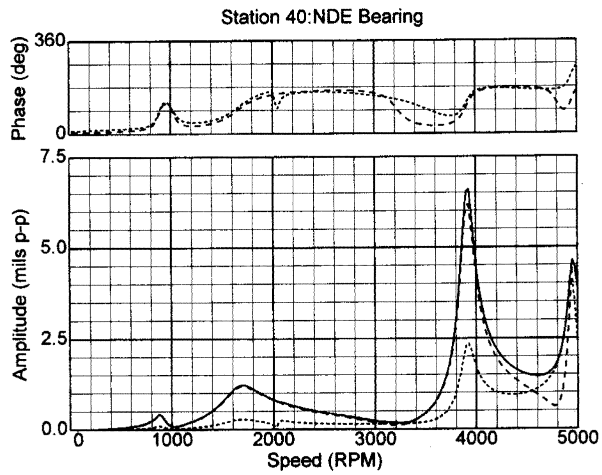

Figure 2. Calculated Unbalance Response at Non-Drive End Bearing.

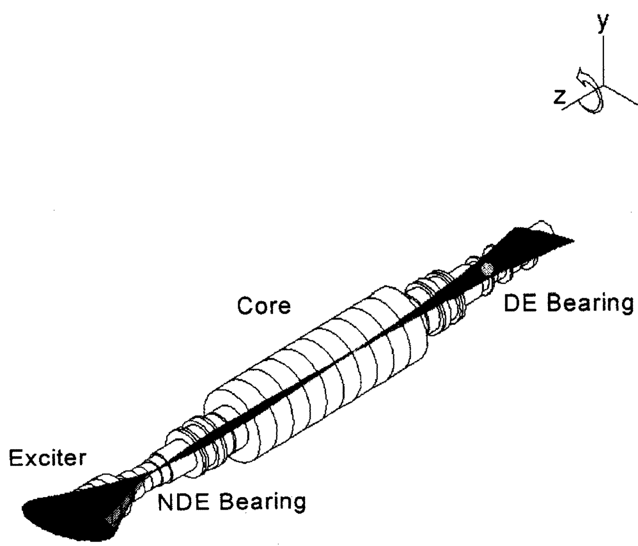

Figure 3. Calculated Unbalance Response Shape at 3,600 RPM.