Vibration Measurement	Variation of Rotating Speed in Load Rejection Test of Steam Turbine	Rotating Machinery

Object Machine

Steam turbine generator, 3,000rpm, 300MW

Observed Phenomena

During load rejection test of the steam turbine generator, a fluctuation period of 0.8sec (frequency is 1.25Hz and maximum Variation speed is 25rpm at 3,300RPM) was observed. superimposed on the number of revolutions of the turbine. By FEM calculation, the 1st torsional natural frequency of the turbine-generator main shaft system was 18.5Hz, thus, it was made clear that this fluctuation period did not agree with the torsional vibrations of the shaft system.

Cause Estimation

Following are the estimated causes for the fluctuation period 0.8sec superimposed on the rotational period of the turbine during load rejection test:

- Resonance of the turbine frame or the bracket for mounting a rotating speed detector.
- The torsional natural frequency of the shaft system (for comparison of calculation and measurement)
- Aliasing phenomenon in the digital sampling 50msec (20Hz) for the calculator of rotating speed of turbine

Analysis and Data Processing

- The result of hammering excitation test of the mounting bracket for mounting a rotating speed detector proved that the natural frequency is sufficiently higher than rotating speed of the turbine.
- Vibrations of the turbine pedestal immediately after load rejection could not amplify the rotational fluctuations.
- Release of torque due to load rejection excited transient torsional vibrations of the turbine-generator shaft system. Measurement results proved that the primary torsional natural frequency of the shaft system was 18.75Hz, while the rate of variations in rotating speed was 0.72% (± 12 CPM at 3,276RPM). The natural frequency agreed well with the FEM calculation.
- From the above it was found that the cause of the rotational fluctuations of 0.8sec period (1.25Hz) measured and recorded in the chart recorder was a 1.25Hz ghost signal that was generated by 18.75Hz torsional vibrations under the influence of the computer sampling (20Hz).

Countermeasures and Results

Output sampling for computing turbine number of revolutions was fixed at 50msec (20Hz), while the torsional natural frequency of the turbine-generator shaft system excited in the load rejection test did not satisfy the sampling theorem that the sampling frequency should be more than twice of signal frequency which is 2x18.75Hz = 37.5Hz. Thus,

20.0Hz - 18.75Hz = 1.25Hz

By the folding effect of differences between the sampling frequency and the torsional vibration signal, a 1.25Hz (period 0.8sec) ghost signal was appeared. The rotational fluctuation period measured by the chart recorder was the cause of this ghost signal that was generated by the so-called aliasing to occur from the torsional vibration under the influence of discrete sampling.

Variations in the number of revolutions caused by load rejection are transient torsional vibrations acting on the shaft system. The excited torsional vibration itself is not an abnormal vibration, and it has become clear that 1.25Hz rotational fluctuation period is aliasing. Thus, the sampling period was changed to 20msec (50Hz) to avoid generation of aliasing, and thus the above phenomenon has been eliminated.

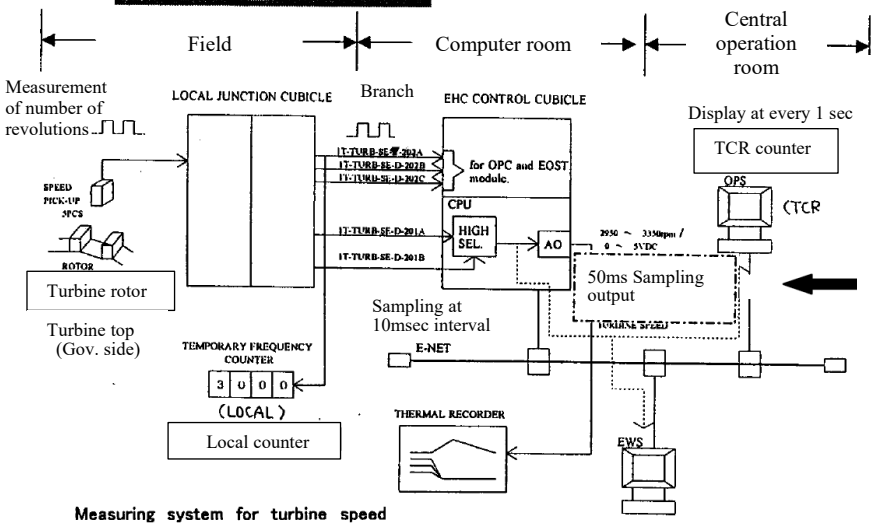
Lesson

In case of sampling by discretization of the time axis of continuous analog waveforms, the interval defined by the sampling theorem shall be used. If not, the original waveform information can not be faithfully reproduced. If a sampling interval longer than the specified one is selected, not only higher harmonic components of the waveforms will be lost, but entirely different waveform may be generated to cause errors, thus attention shall be paid.

Keywords

Steam turbine, torsional vibration, aliasing, load rejection, sampling

Block diagram of measuring system for turbine number of revolutions



Measuring system for turbine speed

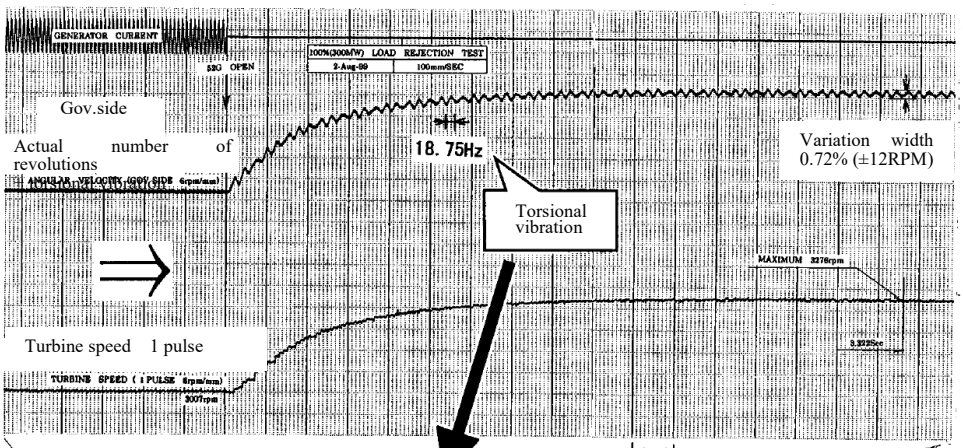
(Normal Instrument)

In order to reproduce the torsional natural frequency of 18.75Hz faithfully, the sampling interval was changed to 20msec (50Hz), so as to satisfy the sampling theorem, that the sampling frequency should be more than two times of signal, that is 2x18.75=37.5Hz.

Results of measurement

1. Investigation into the cause of variations in the number of revolutions

Torsional vibration measurement chart



Computer sampling 50msec 20.0Hz — Primary torsional natural frequency 18.75Hz = Ghost signal due to aliasing 1.25Hz

Test result of 100% load rejection

Pen chart measurement record