Analysis and Treatment of Generator Vibration Faults in a Power Plant

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Abstract. This paper presents a detail research on a vibration high fault after overhaul occurred on a generator. During the overhaul, the generator rotor is returned to factory for processing and replaces section across the line of the generator excitation end. The gas turbine unit vibrates high in the idle 3000 r·min⁻¹ and full load. The large vibration of the generator is mainly caused by the following two factors: the imbalance in the overhanging end of the generator rotor and the electrical fault in the generator itself. The unbalanced amount of generator overhang was successfully eliminated by dynamic balance test. The electrical fault of generator itself needs to be returned to the factory to handle.

1. Introduction
The No.3 PG9171E gas turbine unit of a power plant is produced by American GE Company. Its rated speed is 3000r·min⁻¹ and the rated power is 120MW. The gas turbine and generator are connected by load coupling. The generator set has a total of 5 bearings, a 3-stage gas turbine rotor and a 17-stage axial flow compressor rotor adopt a three-support structure, and the generator rotor adopts two support structures. The shafting structure of the unit is shown in Figure 1.

![Figure 1. PG9171E shafting arrangement of gas turbine generator](image-url)
Looking from the turbine to the generator

Figure 2. Sensor arrangement

The unit phase-sensing sensor is installed near the No. 1 bearing, and two shaft vibration sensors are installed on the No. 1, No. 3, No. 4, No. 5 bearings, and the cover vibration sensors are installed on the No. 1 to No. 5 bearings. Among them, due to the limitation of the space structure of the gas turbine, the bearing vibration sensor of No. 2 bearing is installed below, which is different from other sensors.

The unit was overhauled in May 2016. During the start-up operation of the generator, the vibration of the generators changed greatly. The vibration of the No. 5 bearing reached 160μm during the start-up of the unit. Therefore, the phenomenon and the cause of large vibration of the unit are analyzed. Through on-site dynamic balance, the vibration of the unit is effectively reduced, and the unit is restored to safe operation.

2. Phenomenon and failure

Before the generator rotor of the unit is returned to the factory for maintenance, the vibration of the unit is shown in Table 1.

| Measuring point | Start 3000 r·min⁻¹ | 1 day later 120MW | 3 days later 120MW | Stop 3000 r·min⁻¹ |
|----------------|---------------------|-------------------|-------------------|------------------|
| 4X             | 0.04                | 0.07              | 0.06              | 0.06             |
| 4Y             | 0.04                | 0.11              | 0.07              | 0.06             |
| 5X             | 0.06                | 0.21              | 0.15              | 0.12             |
| 5Y             | 0.02                | 0.07              | 0.05              | 0.04             |

When the generator rotor was returned to the factory during the overhaul in May 2016, it was found that the crossover of the partial coil group was deformed and the over-line replacement was performed.

The unit started after the repair on June 13, 2016. Looking at the historical situation, it was found that the generator excitation vibration was still too large during the operation and load process.

3. Vibration Analysis

Vibration data analysis. Data collection was performed on the vibration of the unit in December 2016. Table 2 shows the vibration data at the start, fixed and full load before the dynamic balance test. By doing the excitation current test of the generator, it is found that the vibration of the No. 4 bearing and the No. 5 bearing varies with the excitation current of the generator.

When the influence coefficient is known, the test weight and angle can be directly calculated from the influence coefficient and the original vibration, which is relatively simple. When the influence coefficient is unknown, it is necessary to estimate the magnitude and angle of the original vibration estimation, and there are many factors to consider.
3.1 Vibration data analysis

Data collection was performed on the vibration of the unit in December 2016. Table 2 shows the vibration data at the start, fixed and full load before the dynamic balance test. By doing the excitation current test of the generator, it is found that the vibration of the No. 4 bearing and the No. 5 bearing varies with the excitation current of the generator.

Table 2. Vibration data before dynamic balance test

| Measuring point | 1321 r·min⁻¹ | 3000 r·min⁻¹ | 120MW |
|-----------------|---------------|---------------|-------|
| 4X              | 0.06/0.05     | 0.06/0.05     | 0.09/0.08 |
| 4Y              | 0.05/0.04     | 0.03/0.03     | 0.05/0.05 |
| 5X              | 0.05/0.05     | 0.13/0.12     | 0.16/0.15 |
| 5Y              | 0.08/0.07     | 0.05/0.04     | 0.06/0.05 |

As can be seen from the above data, the vibration of the unit has the following characteristics:

1. When the critical speed of the unit is 1321 r·min⁻¹, the shaft vibrations of No. 4 and No. 5 are good, indicating that the first-order unbalance component is not large.
2. When the unit is idling 3000 r·min⁻¹, the vibration reaches 130μm, of which 1X is the main, indicating that there is a certain imbalance fault.
3. It can be seen that the vibration of the No. 4 bearing and the No. 5 bearing changes synchronously with the excitation current of the generator, and there is no hysteresis between the two. It indicates that there is an electrical fault at the same time. There is an unbalanced electromagnetic force in the generator rotor.

3.2 Vibration form determination

The judgment of the unbalanced form of the rotor at the working speed is complicated, and is greatly affected by mutual interference between the rotors and the form of support [1]. Vibrations at operating speeds can occur in two situations:

1. The inverse component is obvious, indicating that the rotor has an antisymmetric form of imbalance. The sensitivity of the antisymmetric component at the operating speed is usually higher, and such vibrations are easier to balance [2].
2. The same phase component is obvious. There are three possibilities for the in-phase component of vibration at operating speed: first-order imbalance, third-order imbalance, and rotor out-of-extension end imbalance.

The first-order imbalance can be weighted in the middle of the rotor or a symmetrical form of weight at the end of the rotor. In most cases, the symmetrical form weight has a low sensitivity and the weight is usually large.

The handling of third-order unbalanced faults is cumbersome. In order to balance the third-order vibration component without affecting the first-order vibration component, it is known from the vibration theory that it needs to be weighted on three planes of the rotor. However, many units can only be weighted on the two planes of the end when they are balanced on site. This may lead to contradictions in the vibration at the operating speed and the critical speed, the situation cannot be met at the same time. Fortunately, the third-order imbalance will only occur on the rotor with a very low critical speed. For thermal power units, it is usually only necessary to consider the effects of the third-order mode when the generator rotor is balanced [3].

When the outer end of the rotor is long and heavy, it will cause distortion of the inner rotor mode and may induce in-phase vibration. In addition, the imbalance of the rotor's overhanging end itself may also produce such in-phase vibration, and it is very sensitive [4].

It can be seen from the above analysis that after the in-phase vibration component appears at the operating speed, the rotor can be balanced by the method of adding the symmetric weight of the rotor or the extension of the rotor extension end [5].
3.3 On-site dynamic balance test

By further analyzing the data, it is found that this vibration has a large in-phase component. Since the vibration is not large when passing the critical stage, it is excluded that the rotor crosses the internal symmetric weight, and the dynamic balance weight is determined in the exciter. That is to say, 425g ∠340° is added to one side of the exciter. The vibration data after the first dynamic balance is shown in Table 3.

| Measuring point | 3000 r·min⁻¹ | 120MW |
|-----------------|--------------|------|
| 4X              | 0.07/0.04    | 0.09/0.07 |
| 4Y              | 0.04/0.02    | 0.05/0.03 |
| 5X              | 0.10/0.09    | 0.14/0.14 |
| 5Y              | 0.04/0.04    | 0.06/0.05 |

The vibration is reduced compared to the vibration before the dynamic balance. The leakage opportunity of the manhole door seal of the waste heat boiler is used to perform the second dynamic balance adjustment. The adjustment scheme is to remove the first counterweight and add 600g ∠30° on one side of the exciter. The vibration data after the second dynamic balance is shown in Table 3 and Figure 4.

| Measuring point | 3000 r·min⁻¹ | 120MW |
|-----------------|--------------|------|
| 4X              | 0.03/0.01    | 0.06/0.04 |
| 4Y              | 0.03/0.01    | 0.04/0.02 |
| 5X              | 0.05/0.04    | 0.08/0.07 |
| 5Y              | 0.02/0.01    | 0.03/0.03 |

Figure 3. The Vibration data at 120MW

Note: 77RP indicates the speed signal; 11X and 12Y are the shaft vibration of No.1; 31X and 31Y are the shaft vibration of No.3; 91X and 91Y are the vibration of No.4 shaft vibration; 10X and 10Y are the vibration of No.10 shaft vibration.
By performing the dynamic balance test on the exciter, the mechanical unbalance of the generator is eliminated, and the vibration is at most 50 μm when the rotation speed is 3000 r•min⁻¹, which is good. Due to the electrical fault of the generator itself, there is still a 30μm increment when the unit is loaded at 120MW, and it remains basically stable during multiple start-stop operations, and is returned to the manufacturer for processing at a suitable opportunity.

4. Conclusion
The large vibration of the generator is mainly caused by the following two factors:

(1) There is an imbalance in the overhanging end of the generator rotor.
(2) There is an electrical fault in the generator itself.

Through the dynamic balance test on the exciter, the mechanical unbalance is successfully processed, so that the vibration of the unit is significantly reduced and the operation requirements are met. Due to the electrical failure of the generator itself, it cannot be eliminated by the dynamic balance test and needs to be returned to the factory for processing. The successful handling of this fault provides valuable experience for fault management of the same type of unit.

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