Turbine Generator Synchronization — Two Case Studies

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This article presents two case studies of increased vibrations associated with load dispatch and removal from gas turbine–driven synchronous generators during electrical supply synchronizations. The first case involves a classical uneven air gap fault due to a loose foot on the generator. Such faults are readily detected from the 2V line frequency associated with an electrical defect source. Another case involves unusually high transient vibrations during synchronization and not widely reported in the literature. Vibration levels increased during synchronization which, under full load conditions, remained high and resulted in a unit trip due to excessive vibration levels. At partial-load conditions, the high-transient vibrations dropped back down to pre-synchronization levels. Dominant vibration frequency was at 1V synchronous frequency (and not the classical 2V line frequency). This fault was not due to the generators themselves but due to defects involving the synchronization process with likely out-of-phase synchronization.

Turbine generator sets are used in power generation and are connected within a power grid system typically to the electricity grid on a district or a stand-alone power system such as on an offshore oil and gas facility. Common vibration problems in turbine generators often relate to mechanical faults associated with mass unbalance, misalignment and rubs. Problems originating from the generator are less frequent and can often be misdiagnosed by plant operators and third-party personnel. This article presents two case studies of turbine generator vibration problems originating from synchronization of the generator with the electrical power system to which the units were dispatching power.

Synchronous generators convert mechanical energy from a prime mover (typically a gas or steam turbine) to alternating current (AC) electric energy. A direct current (DC) is applied to the rotor winding of a synchronous generator to produce a rotor magnetic field. The prime mover rotates the generator rotor to induce a rotating magnetic field in the machine. A three-phase set of voltages is generated in the stator windings by the rotating magnetic field. For electrical power to be dispatched into the electricity grid (which is at a higher electrical potential), the disconnected generator has to be synchronized into the power network grid. Connecting a synchronous generator to the power system is a dynamic process, requiring the coordinated operation of many components (electrical, mechanical and often human). The goal is to connect the spinning generator to the system when the generator matches the system in voltage magnitude, phase angle and frequency.

Turbine Generator and Synchronization Faults

Problems with turbine generators may be classified as mechanical or electrical/electromagnetic in nature. Typical mechanical vibration problems, as in any rotating machine, are mass unbalance, misalignment and rotor rubs. Mass unbalance occurs due to imbalance in the rotor assembly (from blades of non-identical mass distributions) and for in-service machines usually from lost parts or foreign object damage (FOD).

Such mass unbalance results in high overall vibrations and is easily identified from the increase of the synchronous 1V RPM vibration component in the vibration spectrum as well as from the phase relationships of vibration measured across the turbine generator set. Misalignment occurs from inadequacies in correct alignment of the rotors across the coupling. With in-service machines, this is more often induced via pre-loads due to thermal expansion and problems in the supports instead. Alignment-related faults are easily identified from the synchronous 1V RPM and 2V RPM
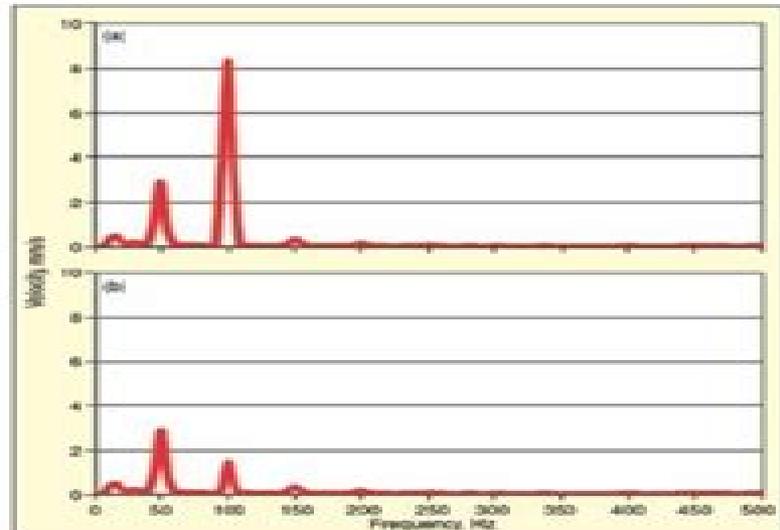

Figure 1. Vibration spectrum generator drive end bearing; (a) with load dispatch and (b) immediately after power removal.

vibration components in the vibration spectrum as well as from the phase relationships of vibration measured across the turbine generator set. Rotor rubs and bearing failures are often the result of excessive vibrations from mass unbalance and/or misalignment. Another occasional problem with in-service equipment can be from loose mounting feet.

Electrical problems are associated with unequal air gaps that pull the rotor more strongly at the location of least gap and cracked or broken rotor bars that move and change the rotor balance under the effects of a magnetic field and centrifugal force. Stator problems, eccentric rotors and phasing problems result in high vibrations at 2V electrical AC frequency (2V line frequency). For synchronous generators this 2V line frequency is also the 2V RPM rotational frequency. Since electrical problems are less frequent, the initial suspect of this 2V synchronous component is a misalignment or preload fault. While an experienced vibration analyst can easily distinguish the mechanical and electrical fault when power is removed, the sequence of events during synchronization is measured in seconds, and differences in vibration behavior could be easily missed. If the problem is electrical in nature, the excessive vibration and particularly the 2V line frequency component would disappear immediately when power is removed. If the problem is mechanical, the vibration components (2V RPM) would decay in proportion to the speed. An example of this diagnostic process using real-time station DCS (distributed control system) monitoring data and FFT spectrum comparison is presented in Case Study 1.

A less frequent problem relates to faults arising from the synchronization process. Electric power systems consist of an interconnection of multiple units of synchronous generators

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