

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 off-shore 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 distribution) 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

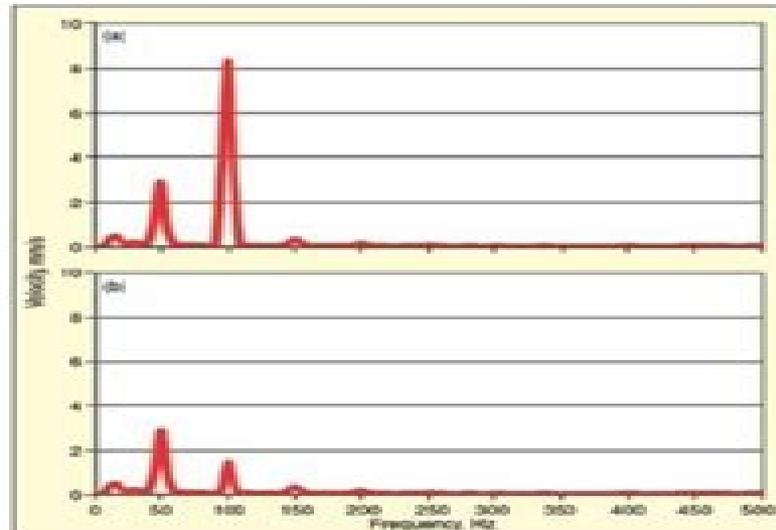


Figure 2. Vibration spectrum generator drive and bearing: (a) with load dispatch; and (b) immediately after power removal.

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.¹ 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 pre-load 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

Turbine Generator Synchronization Two Case Studies

Robert W. Creighton, Jacek Ilow



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Transient Analysis of Power Systems Juan A. Martinez-Velasco, 2020-02-10 A hands on introduction to advanced applications of power system transients with practical examples Transient Analysis of Power Systems A Practical Approach offers an authoritative guide to the traditional capabilities and the new software and hardware approaches that can be used to carry out transient studies and make possible new and more complex research The book explores a wide range of topics from an introduction to the subject to a review of the many advanced applications involving the creation of custom made models and tools and the application of multicore environments for advanced studies The authors cover the general aspects of the transient analysis such as modelling guidelines solution techniques and capabilities of a transient tool The book also explores the usual application of a transient tool including over voltages power quality studies and simulation of power electronics devices In addition it contains an introduction to the transient analysis using the ATP All the studies are supported by practical examples and simulation results This important book Summarises modelling guidelines and solution techniques used in transient analysis of power systems Provides a collection of practical examples with a detailed introduction and a discussion of results Includes a collection of case studies that illustrate how a simulation tool can be used for building environments that can be applied to both analysis and design of power systems Offers guidelines for building custom made models and libraries of modules supported by some practical examples Facilitates application of a transients tool to fields hardly covered with other time domain simulation tools Includes a companion website with data input files of examples presented case studies and power point presentations used to support cases studies Written for EMTP users electrical engineers Transient Analysis of Power Systems is a hands on and practical guide to advanced applications of power system transients that includes a range of practical examples [Disturbance Analysis for Power Systems](#) Mohamed A. Ibrahim, 2011-09-28 More than ninety case studies shed new light on power system phenomena and power system disturbances Based on the author s four decades of experience this book enables readers to implement systems in order to monitor and perform comprehensive analyses of power system disturbances Most importantly readers will discover the latest strategies and techniques needed to detect and resolve problems that could lead to blackouts to ensure the smooth operation and reliability of any power system Logically organized Disturbance Analysis for Power Systems begins with an introduction to the power system disturbance analysis function and its implementation The book then guides readers through the causes and modes of clearing of phase and ground faults occurring within power systems as well as power system phenomena and their impact on relay system performance The next series of chapters presents more than ninety actual case studies that demonstrate how protection systems have performed in detecting and isolating power system disturbances in Generators Transformers Overhead transmission lines Cable transmission line feeders Circuit breaker failures Throughout these case studies actual digital fault recording DFR records oscillograms and numerical relay fault records are presented and analyzed

to demonstrate why power system disturbances happen and how the sequence of events are deduced The final chapter of the book is dedicated to practice problems encouraging readers to apply what they ve learned to perform their own system disturbance analyses This book makes it possible for engineers technicians and power system operators to perform expert power system disturbance analyses using the latest tested and proven methods Moreover the book s many cases studies and practice problems make it ideal for students studying power systems

CCECE 2000, CCGEI 2000, IEEE CCECE 2000, Navigating to a New Era Robert W. Creighton, Jacek Ilow, 2000 **Computer Aided Design and Applications** International Association of Science and Technology for Development, 1985 *Power System Dynamics* Jan Machowski, Zbigniew Lubosny, Janusz W. Bialek, James R. Bumby, 2020-02-20 An authoritative guide to the most up to date information on power system dynamics The revised third edition of *Power System Dynamics and Stability* contains a comprehensive state of the art review of information on the topic The third edition continues the successful approach of the first and second editions by progressing from simplicity to complexity It places the emphasis first on understanding the underlying physical principles before proceeding to more complex models and algorithms The book is illustrated by a large number of diagrams and examples The third edition of *Power System Dynamics and Stability* explores the influence of wind farms and virtual power plants power plants inertia and control strategy on power system stability The authors noted experts on the topic cover a range of new and expanded topics including Wide area monitoring and control systems Improvement of power system stability by optimization of control systems parameters Impact of renewable energy sources on power system dynamics The role of power system stability in planning of power system operation and transmission network expansion Real regulators of synchronous generators and field tests Selectivity of power system protections at power swings in power system Criteria for switching operations in transmission networks Influence of automatic control of a tap changing step up transformer on the power capability area of the generating unit Mathematical models of power system components such as HVDC links wind and photovoltaic power plants Data of sample benchmark test systems *Power System Dynamics Stability and Control* Third Edition is an essential resource for students of electrical engineering and for practicing engineers and researchers who need the most current information available on the topic **PICA Conference Proceedings**, 1977

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