

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

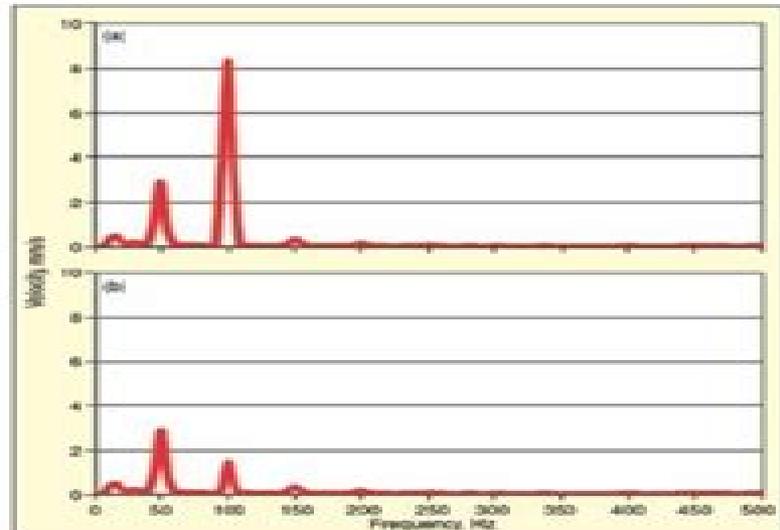


Figure 2. Vibration spectrum generator drive and bearing: (a) with load dispatch; and (b) immediately after power removal.

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

Wenbin Ji



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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

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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

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PICA Conference Proceedings ,1977

Scientific and Technical Aerospace Reports ,1977-05

Power Industry Computer Applications Conference, PICA ,1977

Torsional Vibration of Turbo-Machinery Duncan Walker, 2003-10-31

Vibration excessive noise and other dynamics related problems that limit or prevent operation are a major manufacturing concern in airplanes auto crankshafts home appliances etc This detailed monograph provides in depth coverage of state of the art vibration analysis techniques used to prevent design and operational malfunction Torsional vibration mathematical modeling Forced response analysis Vibration measurement methods and monitoring Application case studies SI units used throughout

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Japan Shipbuilding & Marine Engineering ,1970

Civil Engineering Hydraulics Abstracts ,1984

Japan Shipbuilding

and Marine Engineering ,1970 Power System Restoration M. M. Adibi,2000-06-22 At a time when bulk power systems operate close to their design limits the restructuring of the electric power industry has created vulnerability to potential blackouts Prompt and effective power system restoration is essential for the minimization of downtime and costs to the utility and its customers which mount rapidly after a system blackout Power System Restoration meets the complex challenges that arise from the dynamic capabilities of new technology in areas such as large scale system analysis communication and control data management artificial intelligence and allied disciplines It provides an up to date description of the restoration methodologies and implementation strategies practiced internationally The book opens with a general overview of the restoration process and then covers Techniques used in restoration planning and training Knowledge based systems as operational aids in restoration Issues associated with hydro and thermal power plants High and extra high voltage transmission systems Restoration of distribution systems Power System Restoration is essential reading for all power system planners and operating engineers in the power industry It is also a valuable reference for researchers practicing power engineers and engineering students Sponsored by IEEE Power Engineering Society Conference Publication ,1989
Proceedings - International Conference on Large High Voltage Electric Systems (CIGRE). International Conference on Large High Voltage Electric Systems,1990 *International Aerospace Abstracts* ,1999 **Electrical & Electronics Abstracts** ,1997 *NASA Patent Abstracts Bibliography: A Continuing Bibliography. Section 2: Indexes (supplement 39)* ,1991 *Government Reports Announcements & Index* ,1996-04

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Table of Contents Turbine Generator Synchronization Two Case Studies

1. Understanding the eBook Turbine Generator Synchronization Two Case Studies
 - The Rise of Digital Reading Turbine Generator Synchronization Two Case Studies
 - Advantages of eBooks Over Traditional Books
2. Identifying Turbine Generator Synchronization Two Case Studies
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Turbine Generator Synchronization Two Case Studies
 - User-Friendly Interface
4. Exploring eBook Recommendations from Turbine Generator Synchronization Two Case Studies
 - Personalized Recommendations
 - Turbine Generator Synchronization Two Case Studies User Reviews and Ratings
 - Turbine Generator Synchronization Two Case Studies and Bestseller Lists
5. Accessing Turbine Generator Synchronization Two Case Studies Free and Paid eBooks
 - Turbine Generator Synchronization Two Case Studies Public Domain eBooks
 - Turbine Generator Synchronization Two Case Studies eBook Subscription Services

- Turbine Generator Synchronization Two Case Studies Budget-Friendly Options
- 6. Navigating Turbine Generator Synchronization Two Case Studies eBook Formats
 - ePub, PDF, MOBI, and More
 - Turbine Generator Synchronization Two Case Studies Compatibility with Devices
 - Turbine Generator Synchronization Two Case Studies Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Turbine Generator Synchronization Two Case Studies
 - Highlighting and Note-Taking Turbine Generator Synchronization Two Case Studies
 - Interactive Elements Turbine Generator Synchronization Two Case Studies
- 8. Staying Engaged with Turbine Generator Synchronization Two Case Studies
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Turbine Generator Synchronization Two Case Studies
- 9. Balancing eBooks and Physical Books Turbine Generator Synchronization Two Case Studies
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Turbine Generator Synchronization Two Case Studies
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Turbine Generator Synchronization Two Case Studies
 - Setting Reading Goals Turbine Generator Synchronization Two Case Studies
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Turbine Generator Synchronization Two Case Studies
 - Fact-Checking eBook Content of Turbine Generator Synchronization Two Case Studies
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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