

## CHAPTER- 9

### HYDRO GENERATOR, CHARACTERISTICS AND PERFORMANCE

#### 9.1 GENERAL

The electric generator converts the mechanical energy of the turbine into electrical energy. The two major components of the generator are the rotor and the stator. The rotor is the rotating assembly to which the mechanical torque of the turbine shaft is applied. By magnetizing or "exciting" the rotor, a voltage is induced in the stationary component, the stator. The principal control mechanism of the generator is the exciter-regulator which sets and stabilizes the output voltage. The speed of the generator is determined by the turbine selection, except when geared with a speed increaser. In general, for a fixed value of power, a decrease in speed will increase the physical size and cost of the generator.

The location and orientation of the generator is influenced by factors such as turbine type and turbine orientation. For example, the generator for a bulb type turbine is located within the bulb itself. A horizontal generator is usually required for small turbine e.g. tube turbine and a vertical shaft generator with a thrust bearing is appropriate for vertical turbine installations.

Conventional cooling on a generator is accomplished by passing air through the stator and rotor coils. Fan blades on the rotating rotor assist in the air flow. For larger generator (above 5 MVA capacity) and depending on the temperature rise limitations of the winding insulation of the machine, the cooling is assisted by passing air through surface air coolers, which have circulated water as the cooling medium.

Large Generators interconnected with the grid should meet grid standards issued by Central Electricity Authority (CEA) (relevant extracts are enclosed as annexure-1).

#### 9.2 Hydro Generators Early Designs

##### 9.2.1 Large Hydro

Large salient pole hydro generators specified for installation up to 1970 were constrained by following considerations.

Insulation Systems for Stator and Rotor was Class B insulation with organic binding material which permitted lower temperature rises.

Material for rotor rim punching etc. required limiting the diameter of the rotor so as to permit operation at runaway speed.

Bearing arrangements: Top thrust and guide bearing supported on heavy brackets, capable of supporting total generator weight was provided with a bottom guide bearing to all hydro generators including slow speed large generator which constitutes majority of large hydro generators. This resulted in high cost of machine and building.

Shaft mounted excitation systems were slow and unable to meet the requirements of quick response required from large generators feeding large modern grid systems.

Stability requirements for long distance transmission lines required to feed distant load centre/grids was achieved by manipulating reactances, excitation response ratio and flywheel effect. This resulted in large size of the machine.

Grids were small and there was no stringent requirement for voltage and frequency variation.

Typical section arrangement for Bhakra Left bank machines (100 MVA; 166.7 RPM) with top thrust and guide bearing and bottom guide bearing is shown in figure 9.1 and the capability curve is shown in figure 9.2.

# Chapter 9 Hydro Generator Characteristics And Performance

**G Thomas**



## **Chapter 9 Hydro Generator Characteristics And Performance:**

**Design Optimization of Renewable Energy Systems Using Advanced Optimization Algorithms** Venkata Rao Ravipudi, Hameer Singh Keesari, 2022-03-01 This book describes applications of Jaya and Rao algorithms on real case studies concerning different renewable energy sources. In the last few decades, researchers have focused on renewable energy resources like solar energy, bio energy, wave energy, ocean thermal energy, tidal energy, geothermal energy, and wind energy. This has resulted in the development of new techniques and tools that could harvest energy from renewable energy sources. Many researchers and scientists have focused on developing and optimizing the energy systems to extract and utilize renewable energy more efficiently. In this book, recently developed Jaya and Rao 1, Rao 2, and Rao 3 algorithms are introduced for single and multi objective optimization of selected renewable energy systems. The results of applications of the different versions of Jaya and Rao algorithms are compared with the other optimization techniques like GA, NSGA II, PSO, MOPSO, ABC, etc. and the performance of the Jaya and Rao algorithms is highlighted compared to other optimization algorithms in the case of renewable energy systems. The book also includes the validation of different versions of the Jaya and Rao algorithms through the application to complex single and multi objective unconstrained benchmark functions. The algorithms and computer codes of different versions of Jaya and Rao algorithms are included in the book that will be very much useful to readers in industry and academic research.

**The Electric Generators Handbook - 2 Volume Set** Ion Boldea, 2005-11-16 The modern world hungers for electricity. Traditionally, this hunger was sated with predominantly constant speed regulated synchronous generators. However, new demands require the stable, quick, and efficient delivery and control offered by variable speed generators. Surveying all of the technologies used to satisfy the world's demand for power, [Electric Generators Handbook - Two Volume Set](#) by Ion Boldea, 2018-10-08. [Electric Generators Handbook - Two Volume Set](#) supplies state-of-the-art tools necessary to design, validate, and deploy the right power generation technologies to fulfill tomorrow's complex energy needs. The first volume, Synchronous Generators, explores large and medium power synchronous generator topologies, steady-state modeling, transients, control design, and testing. Numerous case studies, worked-out examples, sample results, and illustrations highlight the concepts. Fully revised and updated to reflect the last decade's worth of progress in the field, the Second Edition adds coverage of high power wind generators with fewer or no PMs, PM-assisted DC-excited salient pole synchronous generators, autonomous synchronous generators, control line switching, parameter identification for isolated grids, synthetic back-to-back load testing with inverter supply, and more. The second volume, Variable Speed Generators, provides extensive coverage of variable speed generators in distributed generation and renewable energy applications around the world. Numerous design and control examples illustrate the exposition. Fully revised and updated to reflect the last decade's worth of progress in the field, the Second Edition adds material on doubly fed induction generator control under unbalanced voltage sags and nonlinear loads, interior permanent magnet claw pole alternator systems, high

power factor Vernier PM generators PM assisted reluctance synchronous motors generators for electric hybrid vehicles and more

**Synchronous Generators** Ion Boldea, 2015-09-03 Synchronous Generators the first of two volumes in the Electric Generators Handbook offers a thorough introduction to electrical energy and electricity generation including the basic principles of electric generators The book devotes a chapter to the most representative prime mover models for transients used in active control of various generators Then individual chapters explore large and medium power synchronous generator topologies steady state modeling transients control design and testing Numerous case studies worked out examples sample results and illustrations highlight the concepts Fully revised and updated to reflect the last decade's worth of progress in the field this Second Edition adds new sections that Discuss high power wind generators with fewer or no permanent magnets PMs Cover PM assisted DC excited salient pole synchronous generators Present multiphase synchronous machine inductances via the winding function method Consider the control of autonomous synchronous generators Examine additional optimization design issues Illustrate the optimal design of a large wind generator by the Hooke Jeeves method Detail the magnetic equivalent circuit population based optimal design of synchronous generators Address online identification of synchronous generator parameters Explain the small signal injection online technique Explore line switching on or off parameter identification for isolated grids Describe synthetic back to back load testing with inverter supply The promise of renewable sustainable energy rests on our ability to design innovative power systems that are able to harness energy from a variety of sources Synchronous Generators Second Edition supplies state of the art tools necessary to design validate and deploy the right power generation technologies to fulfill tomorrow's complex energy needs

**Variable Speed Generators** Ion Boldea, 2015-09-03 Variable Speed Generators the second of two volumes in the Electric Generators Handbook provides extensive coverage of variable speed generators in distributed generation and renewable energy applications around the world The book delves into the steady state transients control and design of claw pole rotor synchronous induction permanent magnet PM assisted synchronous and switched reluctance starter alternators for electric hybrid vehicles It discusses PM synchronous transverse flux PM and flux reversal PM generators for low speed wind and hydro energy conversion It also explores linear motion alternators for residential and spacecraft applications Numerous design and control examples illustrate the exposition Fully revised and updated to reflect the last decade's worth of progress in the field this Second Edition adds new sections that Address the ride through control of doubly fed induction generators under unbalanced voltage sags Consider the control of stand alone doubly fed induction generators under unbalanced nonlinear loads Detail a stand alone squirrel cage induction generator SCIG with AC output and a low rating pulse width modulated PWM converter Present a twin stator winding SCIG with 50 percent rating inverter and diode rectifier and a dual stator winding induction generator with nested cage rotor Examine interior permanent magnet claw pole alternator systems for more vehicle braking energy recuperation and high power factor Vernier PM generators Depict a PM assisted reluctance

synchronous motor generator for an electric hybrid vehicle and a double stator switched reluctance generator with segmented rotor Describe the grid to stand alone transition motion sensorless dual inverter control of permanent magnet synchronous generators with asymmetrical grid voltage sags and harmonics filtering The promise of renewable sustainable energy rests on our ability to design innovative power systems that are able to harness energy from a variety of sources Variable Speed Generators Second Edition supplies state of the art tools necessary to design validate and deploy the right power generation technologies to fulfill tomorrow s complex energy needs     **Energy Research Abstracts** ,1978     *The Journal of Energy and Development* ,2004     **Direct Energy Conversion** Stanley W. Angrist,1982     *Sci-tech Book Profiles* ,1965 Includes title page table of contents list of contributors preface and all indexes of each book     Modeling and Analysis of Reservoir System Operations Ralph Allen Wurbs,1996     **Energy Abstracts for Policy Analysis** ,1983

**Electrical Engineer's Reference Book** Gordon Rees Jones,1993 First published in 1945 this book maintains its original aims to reflect the state of the art in electrical science and technology and to cater for the needs of practising engineers

*Government Reports Index* ,1975     Hydro Power Joachim Raabe,1985     **The Municipal Index** ,1918     **The Engineering Journal** ,1921     **An Introduction to the Study of Electrical Engineering** Henry Hutchison Norris,1908

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