



Design And Manufacturing Of Generator For 250mva Turbo Generator

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Abstract: This paper presents the study of design and manufacturing of a 250 MVA turbo generator. The objective of this work is to understand the mechanical construction, electrical characteristics, and excitation system of a high-capacity synchronous generator. The study investigates the generator's rotor and stator structure, excitation techniques, and quality testing procedures to evaluate its performance and industrial suitability.

Rotor-Stator Design: Analysis of rotor forging, field winding placement, stator core construction, and armature winding techniques.

Excitation System: Implementation of a brushless excitation system including Permanent Magnet Generator (PMG), AC exciter, and Automatic Voltage Regulator (AVR) for field current control.

Testing and Assembly: Evaluation of insulation integrity, coil performance, and mechanical balance using surge testers, high-voltage testers, VPI systems, and dynamic balancing machines.

Applications: Investigation of the generator's use in thermal and nuclear plants, captive power generation, grid support, and emergency power systems.

The project is expected to provide:

1. A practical understanding of turbo generator design and manufacturing.
2. Industrial knowledge of brushless excitation systems and quality testing.
3. Real-world applications and performance insights of a 250 MVA generator.

This paper contributes to the field of power engineering by offering technical exposure to large-scale generator systems and their role in modern energy infrastructure.

Index Terms – Turbo Generator, Rotor, Stator, Excitation System, 250 MVA, Power Generation.

I. INTRODUCTION

Turbo generators are high-speed synchronous machines extensively used in large-scale electric power generation systems. Their fundamental function is to convert mechanical energy, delivered typically by a steam turbine, into electrical energy using electromagnetic induction. Among these, 250 MVA turbo generators represent a class of high-capacity machines that operate at high rotational speeds (commonly 3000 RPM for 2-pole, 50 Hz configurations), delivering bulk power to national grids or industrial systems with consistent efficiency and reliability. Built upon the principles of Faraday's law of electromagnetic induction, turbo generators are composed of a rotating field (rotor) and a stationary armature (stator). When the rotor, supplied with a direct current (DC) excitation, spins within the stator core, it generates a rotating magnetic field, which induces three-phase alternating voltage in the stator windings. This voltage is then stepped up through transformers for transmission to the grid or industrial loads. The design of a 250 MVA turbo generator is significantly more complex than that of smaller machines, requiring careful consideration of mechanical dynamics, insulation coordination, thermal management, and electromagnetic field control.

These machines often employ a brushless excitation system, comprising a permanent magnet generator (PMG), an AC exciter, and a rotating diode rectifier, to eliminate wear-prone brushes and slip rings while maintaining stable field current supply. Automatic Voltage Regulators (AVRs) are integrated to dynamically adjust excitation based on terminal voltage, load variations, and grid conditions. The significance of turbo generators in power systems lies in their ability to deliver high reliability and long-term continuous operation under demanding load conditions. They are indispensable in thermal power plants, nuclear generation facilities, and heavy industrial captive power plants. Their performance directly influences the stability of the power grid, the efficiency of energy conversion, and the operational economics of the power generation infrastructure.

This paper presents a technical review and analysis of the design, construction, and system architecture of a 250 MVA turbo generator. It highlights the key subsystems including the rotor, stator, excitation system, and control mechanisms. Emphasis is also placed on the manufacturing processes, quality assurance testing, and potential applications of such machines in modern electric power systems.

II IMPORTANCE OF 250 MW TURBO GENERATOR IN INDUSTRIAL APPLICATIONS

Turbo generators rated at 250 megavolt-amperes (MVA) are critical components in high-demand power generation systems. Their primary function is to supply continuous, large-scale electrical power in thermal and nuclear power stations, as well as in industrial captive generation units. These generators are typically used in conjunction with steam turbines to deliver stable, high-voltage, three-phase AC power to grids or industrial networks.

In industries such as steel, cement, petrochemicals, and refineries, these generators support large-scale processes by providing the necessary electrical power for heavy machinery, auxiliary systems, and process automation. Additionally, they are widely used in base-load generation for public utilities, where their long service life, low maintenance requirements, and reactive power support capabilities contribute significantly to grid reliability and system stability.

III SCOPE OF THE REPORT

This report offers a comprehensive analysis of the design and manufacturing process of a 250 MVA turbo generator, focusing on its mechanical structure, electrical configuration, and industrial applications. It highlights the essential components of the generator—such as the rotor, stator, excitation system, and voltage regulation system—and examines how these subsystems function together to produce reliable high-capacity power.

The study includes insights into industrial manufacturing techniques such as coil looping, insulation taping, vacuum pressure impregnation (VPI), rotor dynamic balancing, and high-voltage testing. It also explores modern advancements in excitation systems, particularly the use of brushless technology with Permanent Magnet Generators (PMG), rotating diode bridges, and Automatic Voltage Regulators (AVR).

By analysing real-world implementation scenarios, this report outlines the operational advantages and limitations of 250 MVA turbo generators in various sectors including thermal power generation, industrial captive units, and emergency power systems. The goal is to provide a well-rounded understanding of how such machines are engineered, tested, and deployed in practice, and to highlight their ongoing relevance in global energy infrastructure.

IV BLOCK DIAGRAM

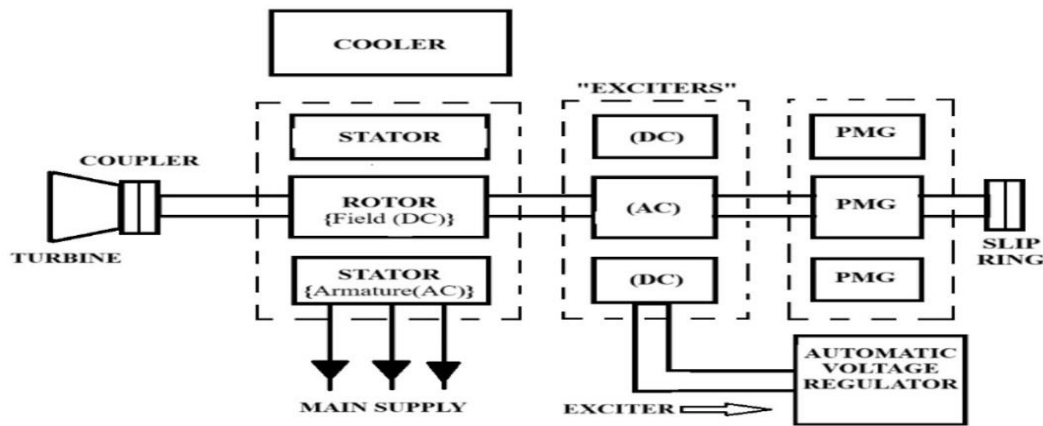


Fig: BLOCK DIAGRAM OF 250 MVA TURBO GENRATOR

V POWER FACTOR CORRECTOR

In an AC system, **power factor (PF)** is the ratio of real power (kW) to apparent power (kVA). A PF of **1.0 (unity)** indicates efficient power usage, while a lower PF suggests reactive power losses.

Large synchronous generators like the **250 MVA turbo generator** often operate at a **lagging power factor** due to inductive loads or under excitation. A poor power factor can lead to:

- Higher energy charges
- Increased system losses
- Voltage drops and instability
- Overloaded cables and transformers

To correct this, turbo generators use their **excitation system**. By adjusting the **field current** via the **AVR (Automatic Voltage Regulator)**:

- **Overexcitation** leads to a **leading PF** (supplying reactive power)
- **Under excitation** results in a **lagging PF** (absorbing reactive power)

This dynamic control helps maintain a **desired PF (e.g., 0.95)**, improving system efficiency and stability.

VI OPERATION OF THE 250MVA TURBO GENERATOR

A 250 MVA turbo generator operates on the principle of **electromagnetic induction**, where mechanical energy from a steam turbine is converted into three-phase electrical energy.

1. Mechanical Drive (Turbine Input)

High-pressure steam rotates the **turbine shaft**, which is directly coupled to the **rotor** of the generator. This rotor spins at **synchronous speed (3000 RPM)** for a 2-pole, 50 Hz system.

2. Rotor Excitation

The rotor contains **field windings** excited by **DC current** through a **brushless excitation system**. This creates a **rotating magnetic field**.

3. Electromagnetic Induction in the Stator

The rotating magnetic field from the rotor **cuts through the stator windings**, which are stationary. This induces a **three-phase AC voltage** in the stator coils based on **Faraday's Law**.

4. Voltage Regulation

The **Automatic Voltage Regulator (AVR)** continuously adjusts rotor excitation to keep the terminal voltage stable under varying load conditions.

5. Power Output

The generated **AC power (typically at 15.75 kV)** is sent to a **step-up transformer** and then fed to the grid or industrial loads.

VII LOSSES IN 250MVA TURBO GENERATOR

Like all large rotating electrical machines, **250 MVA turbo generators** experience internal losses that reduce their overall efficiency. These losses are categorized as follows:

1. Copper Losses (I^2R Losses)

- Occur in both **stator and rotor windings** due to electrical resistance.
- Increase with load current and affect generator heating.
- These are the **major variable losses** during operation.

2. Iron Losses (Core Losses)

- Occur in the **laminated stator core**.
- Include:
 - **Hysteresis losses** (due to magnetic field reversal)
 - **Eddy current losses** (induced circulating currents)
- These are constant losses dependent on supply voltage and frequency.

3. Mechanical Losses

- Arise due to **friction in bearings** and **air friction (windage)** from rotor rotation.
- Increase slightly with speed but are generally constant.

4. Stray Load Losses

- Include losses due to **leakage flux, harmonic currents, and non-uniform current distribution**.
- Though small, they become noticeable in **high-power machines**.

VIII EFFICIENCY IMPROVEMENT METHODS

Due to the high-power output and continuous operation of **250 MVA turbo generators**, improving efficiency is essential to reduce losses, lower operating costs, and enhance reliability. The following methods are commonly employed:

1. Optimized Cooling Systems

Advanced cooling techniques such as **hydrogen or water-cooling** improve heat dissipation, keeping internal temperatures within limits and reducing copper and iron losses.

2. High-Grade Insulation

Use of **Class F or H insulation** with superior thermal properties increases dielectric strength, minimizes energy losses, and enhances winding life.

3. Superior Magnetic Materials

Employing **laminated low-loss silicon steel** in the stator core reduces eddy current and hysteresis losses.

4. Precision Manufacturing

Tight mechanical tolerances and accurate alignment minimize **friction, windage, and mechanical losses**, while ensuring better magnetic coupling.

5. Brushless Excitation and AVR Control

Modern **brushless excitation systems** and **Automatic Voltage Regulators (AVRs)** ensure optimized field current, avoiding overexcitation and reducing unnecessary reactive power losses.

IX TESTING AND DIAGNOSTIC

Due to the critical nature and high cost of 250 MVA turbo generators, **routine testing and condition monitoring** are essential to ensure safe operation, compliance with standards, and early fault detection.

1. Performance Testing

- Includes **no-load**, **short-circuit**, and **load tests**.
- Parameters such as **efficiency**, **voltage regulation**, **temperature rise**, and **vibration** are measured.
- Tests are conducted as per **IEC 60034** and relevant factory acceptance test standards.

2. Insulation Resistance Testing

- Conducted using a **megohmmeter** to verify insulation health between windings and ground.
- Helps in identifying **moisture**, **aging**, or **contamination** of insulation systems.

3. Core Testing (EL-CID)

- **Electromagnetic Core Imperfection Detection** is used to identify inter-laminar faults in the stator core before winding.

4. High Voltage and Surge Testing

- Verifies insulation withstand strength by applying test voltages (e.g., 30–50 kV).
- **Surge comparison testers** detect inter-turn insulation breakdown.

5. Rotor Balancing and Vibration Testing

- Performed on **dynamic balancing machines** to ensure minimal vibration at operating speed.
- Vibration is measured and analysed per **ISO 10816** standards.

Diagnostic Tools

- **Infrared Thermography**: Detects hot spots in coils, bearings, or connections.
- **Electrical Signature Analysis**: Assesses waveform quality for detecting rotor issues and excitation faults.
- **Online Monitoring Systems**: Continuously track parameters like temperature, vibration, and terminal voltage for predictive maintenance.

X FUTURE DEVELOPMENTS IN TURBO GENERATOR DESIGN

As the demand for **higher efficiency**, **reliability**, and **grid adaptability** increases, the design of large turbo generators is evolving to meet modern energy challenges. Future developments focus on improving **thermal performance**, **digital control**, and **sustainability** in high-capacity machines like 250 MVA generators.

Advancements in **magnetic materials** and **low-loss laminations** will reduce core losses, while improved **cooling systems**—including hydrogen or direct liquid cooling—will enhance thermal stability and load endurance.

Integration of **real-time digital monitoring**, **smart excitation control**, and **predictive diagnostics** using IoT-based systems will increase operational transparency and reduce unplanned outages. Additionally, research into **high-speed brushless designs**, **modular rotors**, and **lightweight composite housings** is expected to reduce system weight and improve mechanical efficiency.

With increasing focus on **renewable integration**, future turbo generators may also support **grid-forming modes**, **hybrid operation**, and better **fault ride-through** capabilities, making them more adaptive to fluctuating load and generation patterns.

XI CONCLUSION

This paper has examined the essential aspects of **250 MVA turbo generators**, focusing on their design, construction, excitation systems, testing, diagnostics, and efficiency enhancement methods. These high-capacity synchronous machines are indispensable in large-scale power generation systems, providing reliable and continuous operation in thermal, nuclear, and industrial environments.

Through advanced materials, precision manufacturing, and digital monitoring technologies, turbo generators continue to evolve to meet the growing demands for energy efficiency, grid stability, and long-term performance. A clear understanding of their operation, maintenance, and future potential is critical for modern power engineers and energy infrastructure planners.

SUMMARY OF KEY FINDINGS

Design and Construction: Core components such as the **rotor, stator, excitation system, and insulation structure** are designed to handle high electrical, thermal, and mechanical stresses while maintaining long-term operational stability.

Performance and Efficiency: **High power factor operation**, efficient excitation control, and optimized **cooling and insulation systems** are critical to achieving **>98% efficiency** and minimizing losses in continuous operation.

Diagnostics and Maintenance: Routine testing—such as **insulation resistance, vibration monitoring, surge testing, and core diagnostics**—along with **predictive maintenance tools** ensures early fault detection and reduces downtime.

Control and Protection: Use of **Automatic Voltage Regulators (AVR), brushless excitation systems**, and real-time monitoring improves voltage stability and enhances system protection against electrical and thermal faults.

Innovation and Sustainability: Advancements in **low-loss materials, digital control, and smart diagnostics** reflect the growing trend toward **intelligent, energy-efficient, and grid-adaptive turbo generators** in the modern power sector.

FUTURE OUTLOOK FOR TURBO GENERATOR

Looking ahead, turbo generators will continue to evolve in response to the global shift toward **energy efficiency, grid resilience, and sustainable power systems**. Advancements in **materials science**, such as high-grade magnetic cores and insulation, will further reduce losses and enhance thermal performance.

Integration of **smart sensors, real-time diagnostics, and AI-based predictive maintenance** will make turbo generators more intelligent and self-monitoring. Additionally, future systems will feature **modular construction, compact brushless designs**, and improved **fault ride-through** capabilities, enabling better compatibility with **renewable energy grids and hybrid systems**.

These innovations will make large synchronous generators not only more efficient but also more adaptable to the dynamic needs of tomorrow's power infrastructure.

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