CEEAMA™
Consulting Electrical Engineers Association of Maharashtra

CEEAMA *LiveWire*

E-NEWSLETTER

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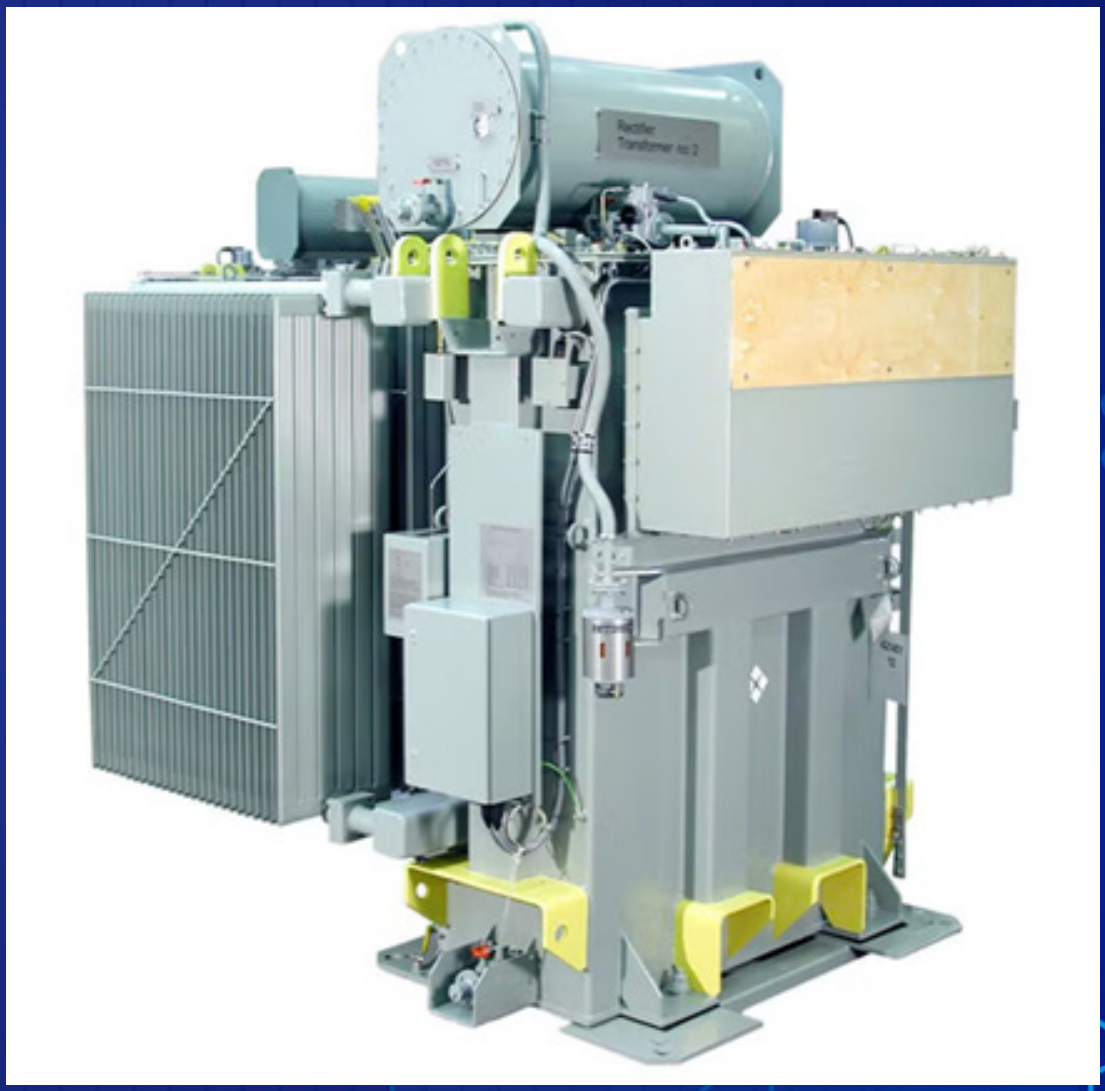

Topic for December 2025

RECTIFIER TRANSFORMER

"Inside: This month's hot topic and smart reads..
Do solve the quiz at the end..!!

Electrical Consultants Newsletter
Volume No. 4 Issue #54
December 2025

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Chief Editor - CEEAMA LIVEWIRE

From the Editors Desk,

**** **** **** ***** **** **Good Bye 2025** **** **** ***** ****

What a year it was!!!

As we pull down the curtains on 2025 and look forward for another fresh new year 2026, let's contemplate on our achievements rather than any failures. Let's greet the new year with more hopes! Actually, HOPE although a positive word, in actual is a negative mindset. When we have hope, it means we are unhappy about the past and the present situation. So let's celebrate the closing of 2025 with cheers, cherishing our proud & happy moments and thanking the almighty for all, everything. Let's be just grateful!

Indeed, we gained a lot in 2025. Let's count our blessings!

First and foremost, I would like to thank our *LiveWire* publishing team of Shailesh Lele & Kaustubh Deshpande, and our contributors including our Secretary and President. There were many occasions of rift and anxiety to bring out the monthly issues on time. But they managed it all resulting in quality newsletter with rich technical contents. We received numerous appreciation emails from different corners from lovable readers like you! Hope to receive your blessings for even better read in 2026!

I would like again to commend our event manager Prabha Enterprises for organising CEEAMATECH with relentless efforts of our past and present GC members!

Our president, Mr. Chidambar V. Joshi cleared his electrical safety auditor exam with commendable 2nd rank. Hearty Congratulations!

Our secretary, Mr. Ulhas Vajre has been requested by the Chief Electrical Inspector of Central Electricity Authority (CEA), Delhi to update the list of standards to be referred in the CEA (measures related to Safety and electric supply) regulations, 2023. Hearty Congratulations sir!

We also celebrated our 21st foundation day on the auspicious day of Gudi-Padwa in April. We also got our new GC members for the next 2 years on the same day!

We organised fun-filled knowledge sessions and networking through sponsored events: 1. M/S. Greycell Energy LLP – 10th August, 2. CEEAMATECH 2024-25 with 3 strong full-day sessions at Lonavala on LV/MV switchgear & protection, 3. Participation of our GC members & LFMs at various events as chairperson/Main speaker/Moderator! The list is big!

I would also like to provide you a consolidated list of topics covered this year: **1. Cathodic Protection, 2. GIS substation, 3. Outdoor Switchyards, 4. Indoor Substation, 5. Electrics in Hazardous Area, 6. Generator, 7. Transmission Line, 8. Energy Audit, 9. EHT, & 10. Rectifier Transformer (this issue).**

Happy Year end and festive season to all our members!!!

**** **** **** ***** **** **WELCOME 2026**** **** ***** ****

P.S. Before I rest my pen on this editorial, I would like to pray for the departed soul of our beloved LFM Mr. S.V. Iyer who left for his heavenly abode on 22nd Oct. 2025. We also lost another member Mr. Kiran Jhaveri on 23rd Nov 2025 and Mr. Prabhuappa Revappa Banale on 3rd August!

Subhash L. Bahulekar
Chief Editor – CEEAMA

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From the President's desk:

Dear Friends,

We stand at the cusp of the sun setting on 2025 and a new sun rise of 2026. The year 2025 has whizzed in front of us and the Indian Power System scenario has looked very promising.

In the first half of 2025, India added about 22 GW of new renewable energy capacity — led by around 18.4 GW of solar and 3.5 GW of wind — the highest six-month renewable addition ever in the country. This accelerated growth was supported by transmission system charge waivers and hybrid solar + Battery Energy Storage Systems (BESS) tenders. By late 2025, India's total installed electricity capacity crossed the milestone where over 50% comes from non-fossil (clean) energy sources — including solar, wind, hydro and nuclear — achieved years ahead of the original 2030 target. BESS received policy focus in 2025, with government and industry working toward scaling tens of gigawatts of storage to support renewables and grid stability — aligning with national targets and investment plans.

The Pinnapuram Integrated Renewable Energy Project (IREP) in Andhra Pradesh began significant operations in 2025. The Pinnapuram (IREP) is the world's first GW-scale project combining solar, wind, and pumped hydro storage to provide firm, on-demand, carbon-free energy, essentially acting as a large "green battery" for India's grid, crucial for green hydrogen/steel and decarbonization goals. With massive solar (1000 MW), wind (550 MW), and pumped storage (1200 MW/10800 MWh) capacities, it solves renewable intermittency, boosting India's energy security and supporting green industries.

The SHANTI Bill 2025 passed recently in the Parliament aims to reform India's nuclear sector by opening civil nuclear power to private investment and partnerships — a major change to boost nuclear capacity and diversify clean energy sources. The Bill is intended to "modernise India's nuclear framework in line with contemporary technological, economic and energy realities, while retaining and strengthening core safety, security and regulatory safeguards that have been in place since the Atomic Energy Act of 1962".

The scene at CEEAMA also looks very promising especially with new Life Fellow Members joining in addition to the new Associate Members. Growth of the engineering community helps in sharing ideas and experiences across the State and beyond. I take an opportunity here to request LFMs to get more active and contact us for leadership positions within the CEEAMA.

Electrical accidents remain a serious concern in India, particularly in residential and construction areas. CEEAMA has always emphasised on proper earthing, safe wiring practices, and appropriate protection devices such as MCBs and RCCBs. In future, CEEAMA plans to conduct safety awareness programs by educating electricians, students, and the public, these groups help reduce fire hazards, electrocutions, and infrastructure damage. As always, CEEAMA emphasizes ethical responsibility, sustainability, and environmental stewardship. By encouraging energy efficiency, responsible resource use, and climate-conscious design, CEEAMA helps align India's development with long-term environmental goals.

In India, electrical engineering communities such as CEEAMA serve as a critical bridge between technology and the society. By applying technical knowledge with social responsibility, CEEAMA members not only power India's infrastructure but also empower the Society. As India moves toward a sustainable and self-reliant future, the role of CEEAMA will remain indispensable. CEEAMA looks forward to a transforming 2026 with many promising programs for its members. Looking forward to meeting you more often.

Merry Christmas and Happy new year 2026

Mr. Chidambar Joshi
Hon. President
CEEAMA

From the Secretary's desk:

Dear Members,

Consulting Electrical Engineers Association of Maharashtra!

As we step into the final month of the year, December invites us to pause, reflect, and look ahead with renewed purpose. For the Consulting Electrical Engineers Association of Maharashtra, 2025 has been a year of steady progress, vibrant technical exchange, and growing collaboration across our fraternity. Each initiative, seminar, and dialogue has strengthened our collective resolve to uphold engineering excellence in an era defined by rapid technological evolution.

This month carries a special significance—marking not just the close of another calendar year, but also offering us the opportunity to celebrate our achievements and recalibrate our goals for the coming one. The landscape of electrical engineering continues to shift with advancements in energy transition, digitalization, grid modernisation, and sustainability. As consultants, we stand at the forefront of this change, shaping safer systems, efficient designs, and smarter infrastructure across Maharashtra and beyond.

In this issue, we bring you insights, expert articles, and updates curated to keep you informed and inspired. I encourage all members to continue contributing your experiences, knowledge, and viewpoints, as your active participation is the foundation of a thriving professional community.

India's continued emphasis on large-scale infrastructure projects, building construction, clean energy transition and emerging technologies has accelerated demand for key industrial materials, with copper emerging as a critical enabler across these sectors.

Copper demand has reached 1,878 kilo-tonnes (kt), driven by India's robust economic progress and the increasing adoption of copper across critical sectors, so the electrical materials as well as services are showing rising trend.

As we prepare to welcome a new year, let us move forward with optimism, curiosity, and a shared commitment to engineering excellence. On behalf of CEEAM,A I extend warm wishes for a joyful and peaceful festive season to you and your families. May 2026 bring new opportunities, growth, and continued technical leadership.

Best Regards,

Mr. Ulhas Vajre

Hon. Secretary

CEEAMA

DISCLAIMER

The information in all the articles of CEEAMA LiveWire is compiled using references from various sources. Although every attempt has been made to ensure the accuracy of this material, neither CEEAMA nor any of its contributors to this publication assumes responsibility for any inaccuracies or omissions in the data presented. For use in practice, we strongly advise that, information utilized from this publication should be verified from the relevant sources and to use document of actual standard published by respective institution.

Rectifier Transformer

DEFINITION

A rectifier transformer is a special type of transformer designed to supply power to rectifiers, which convert alternating current (AC) to direct current (DC).

PURPOSE

The purpose of a rectifier transformer is to supply power to rectifier circuits that convert AC (alternating current) to DC (direct current).

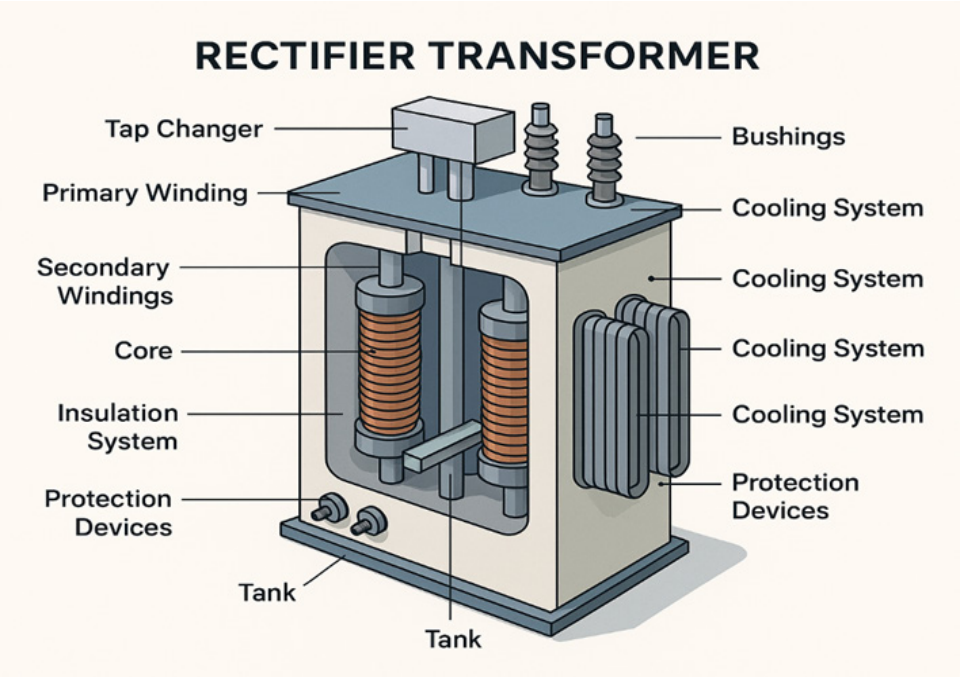
STANDARD RATINGS

- ✓ Primary Voltage: 6.9 kV to 69 kV
- ✓ Secondary Voltage: 2.4 kV to 34.5 kV
- ✓ Capacity: 500 kVA to 20,000 kV

KEY CHARACTERISTICS

- ✓ Multi-Winding Design: Equipped with multiple windings to power several rectifiers simultaneously, ensuring efficient high-capacity performance.
- ✓ High Insulation Strength: Built with reinforced insulation to handle high electrical stress and harmonics during rectification.
- ✓ Harmonic Reduction: Phase-shifting arrangements in the transformer reduce harmonics.

MAJOR PARTS



- ✓ **Core –** Provides magnetic path for flux & minimizes losses.
- ✓ **Primary Winding** – Receives AC supply and creates magnetic flux.
- ✓ **Secondary Windings** – Deliver stepped-up or stepped-down voltage to rectifier.
- ✓ **Tap Changer** – Adjusts output voltage for precise DC control.
- ✓ **Insulation System** – Ensures electrical isolation and safety.
- ✓ **Phase-Shifting Arrangement** – Reduces harmonics in multi-pulse systems**.**

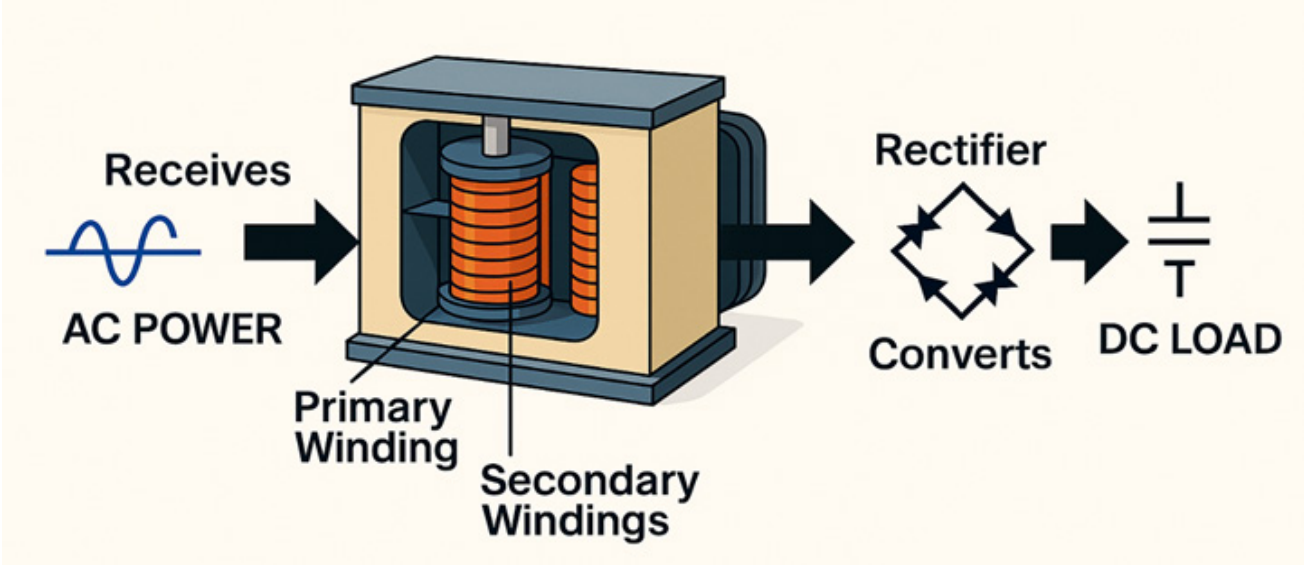
WORKING PRINCIPLE

1. Voltage Transformation

- The primary winding is connected to the AC supply (50 or 60 Hz).
- AC current in the primary creates a time-varying magnetic flux in the core.
- This flux induces voltage in the secondary winding according to Faraday's law.
- The voltage level is adjusted based on the turns ratio to meet rectifier requirements.

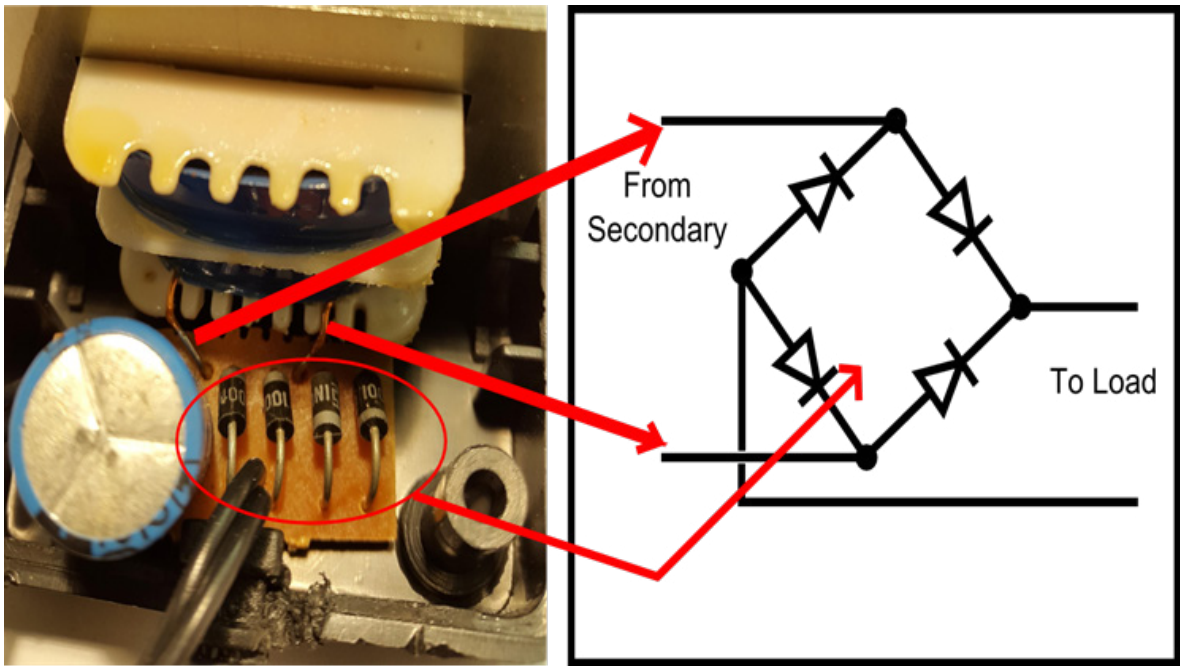
2. Feeding the Rectifier

- Secondary windings deliver the transformed AC voltage to rectifier circuits.
- Windings are arranged for multiple phases (e.g., 6-pulse, 12-pulse, or higher systems)



3. AC to DC Conversion

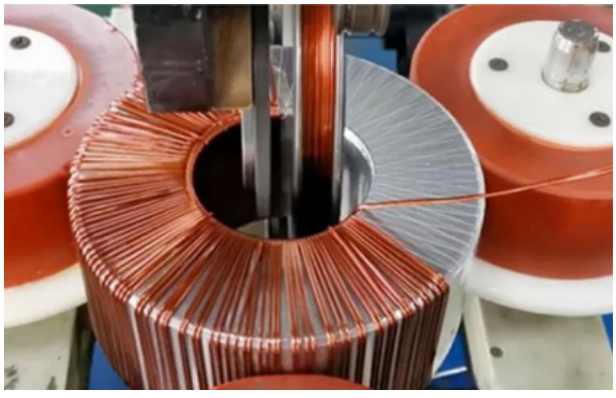
- Rectifier valves (diodes or thyristors) convert AC into pulsating DC.



CONSTRUCTION & MATERIALS

Core Assembly

- ✓ Core Steel
- ✓ Magnetic Shielding



Winding & Insulation

- ✓ High-purity copper conductors
- ✓ Class F or H insulation (e.g. Nomex, and epoxy resin)

Cooling arrangements

- ✓ Oil Natural Air Natural / Air Forced
- ✓ Vacuum-pressure encapsulation for indoors

CONCLUSION

A rectifier transformer is a special transformer that supplies phaseshifted voltages to rectifiers, reducing harmonics and improving DC output quality; it works through star–delta or similar connections and consists mainly of a magnetic core, windings, tap changers, insulation, and cooling systems, making it vital for efficient highpower ACtoDC conversion..

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Rectifier Transformer

1. Design Features & Technical Characteristics

1.1 Multi-Winding Configurations

- Multiple secondary windings with controlled phase shifts (like delta-wye or zigzag with ~30° shifts) helps cancel harmonics and reduce THD (Total Harmonic Distortion).
- Tertiary windings or additional secondaries target elimination of 3rd harmonics.

1.2 Harmonic Management & Phase Shifting

- Multi-pulse systems (6, 12, 24, 48 pulses) mitigate harmonic distortion and improve smoothness.

1.3 Insulation & Winding

- Uses high-grade copper or aluminum conductors sized for continuous DC loads.
- Employs Class F/H insulation (Nomex, epoxy resin) to withstand harmonic-induced heat.

1.4 Core & Magnetic Design

- Laminated grain-oriented silicon steel or amorphous steel minimizes core losses.
- Magnetic shields reduce stray flux and eddy currents.

1.5 Mechanical Robustness.

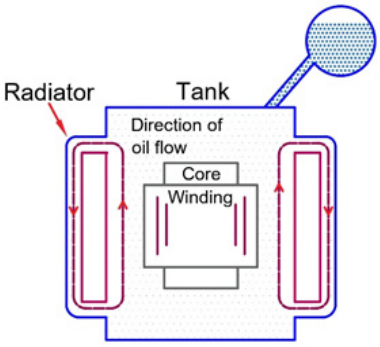
- Built for high thermal inertia, low impedance, vibration damping, and designed to withstand electromagnetic forces during faults or inrush.

1.6 Voltage Regulation

- On-load tap changers (±2.5% to ±10%) allow precise voltage control under varying loads.

1.7 Cooling Systems

- Heat dissipation via Oil-Immersed methods: ONAN or ONAF.
- Dry-type includes natural/forced-air or resin encapsulation for indoor use.



2. Types of Rectifier Transformers

Type	Cooling	Applications
Dry-Type	Air-cooled (natural or forced)	Indoor environments: data centers, medical, clean areas.
Oil-Immersed	ONAN/ONAF	Heavy industrial: steel mills, mining, high-capacity DC loads.
Phase-Shift	Hybrid, oil-cooled	HVDC, large electrochemical plants using 12/24/48-pulse systems

3. Applications

3.1 Electrochemical Processes

- Electrowinning (aluminum, copper, zinc): requires stable low-ripple DC.
- Electroplating and anodizing.

3.2 Steel & Metal Industry

- Electric Arc Furnaces, DC arc welding: manage surges and flicker.
- DC motors in rolling mills and galvanizing lines.

3.3 Traction & Transportation

- Railway substations, metros, trams: 12-pulse systems reduce grid harmonics.
- Marine propulsion systems.

3.4 High Voltage DC (HVDC) Systems

- Converts AC to DC over long distances.
- Used in interconnects and grid stabilization.

3.5 Battery Storage & Renewable Systems

- Charging large energy storage systems and interfacing PV systems with the grid.

4. Performance & Maintenance

4.1 Loss Management

- Core Loss Reduction: Use cold-rolled grain-oriented (CRGO) steel laminations with low hysteresis and eddy current losses.
- Copper Loss Optimization: Employ multi-strand conductors and transposed windings to minimize I^2R losses and improve current distribution.
- Thermal Design: Advanced cooling systems (ONAN, ONAF, OFAF) ensure heat dissipation and maintains efficiency under heavy load.

4.2 Monitoring Tools

- Temperature Sensors: PT100/RTD sensors integrated with SCADA for real-time thermal monitoring.
- Gas Detection: Buchholz relay for early fault detection in oil-filled transformers; dissolved gas analysis (DGA) for predictive maintenance.
- Pressure & Oil Level Devices: Pressure relief valves and magnetic oil level indicators prevent catastrophic failures.

4.3 Lifecycle Checks

- Electrical Tests: Turns ratio test for winding integrity. Insulation resistance and dielectric strength tests for safety compliance.
- Oil Management: Regular oil filtration and moisture removal to maintain dielectric properties. Scheduled oil replacement every 5–7 years depending on contamination levels.
- Predictive Maintenance: Vibration analysis and thermal imaging to detect mechanical stress and hotspots. DGA trend analysis for early detection of internal faults.
- Expected Lifespan Extension: Proper maintenance can extend service life by 10–15 years, reducing total cost of ownership.

5. Comparison with Conventional Transformers

5.1 Load Type

- Rectifier Transformers: Designed for harmonic-rich, non-linear DC loads such as electrolysis, traction, and HVDC systems.
- Conventional Transformers: Deal with balanced and sinusoidal AC loads for general power distribution.

5.2 Secondary Configuration

- Rectifier Transformers: Multi-phase secondary windings (6, 12, or 24-pulse configurations) for smoother DC output and reduced ripple.
- Conventional Transformers: Typical single-phase or three-phase secondary for standard AC supply.

5.3 Design Complexity

- Rectifier Transformers: Incorporate phase-shifting windings, multiple secondary circuits, and harmonic mitigation features.
- Conventional Transformers: Simpler design with standard star or delta connections.

5.4 Cooling & Insulation

- Rectifier Transformers: Require enhanced cooling systems (ONAF, OFAF) and insulation rated for DC stress and harmonic heating.
- Conventional Transformers: Standard cooling (ONAN/ONAF) and insulation for AC voltage stress.

5.5 Regulation & Reliability

- Rectifier Transformers: Equipped with On-Load Tap Changers (OLTC) for precise voltage regulation under fluctuating DC load conditions; rugged design for converter station stress.
- Conventional Transformers: Basic voltage regulation, less exposure to harmonic and DC stresses.

REFERENCES

IEEE Std C57.18.101998 – Practices for Semiconductor Power Rectifier Transformers: Service conditions, harmonic load losses, tests.

IEEE Std C57.911995 – Guide for Loading Mineral-Oil-Immersed Transformers: Loading limits and cooling methods (ONAN, ONAF).

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APPLICATIONS OF RECTIFIER TRANSFORMERS IN MODERN INDUSTRY

INTRODUCTION

- Rectifier Transformer are special transformer designed to supply power to rectifiers, converting AC to DC.
- Importance:
    - Provide controlled DC power.
    - Handle high currents and harmonics.
    - Enable industrial processes, transport systems, and clean energy production.

1. ELECTRIC ARC FURNACES (EAF)

- Rectifier transformers are essential in Electric Arc Furnace (EAF) steelmaking, functioning as the link between the high-voltage AC grid and the furnace to supply the stable, high-current DC power required for melting scrap metal.
- Their specialized design ensures efficient operation and the ability to withstand the extreme electrical and thermal stresses inherent in EAF processes.

ROLE AND FUNCTION

The primary function of the rectifier transformer in an EAF is twofold:

- **Voltage Step-Down**: It steps down the high-voltage AC from the power grid to a much lower, suitable voltage level (typically hundreds of volts).
- **AC-to-DC Conversion Link**: It acts as the crucial link to a rectifier unit (composed of diodes or thyristors) which converts the stepped-down AC into high-current DC power.

This stable, high-current DC power sustains a powerful electric arc between the graphite electrodes and the metallic charge, generating the intense heat necessary for efficient melting and refining of metals.

BENEFITS

The application of rectifier transformers in EAFs offers several key benefits:

- **Efficient Melting Process:** Provides the highly stable and controllable DC power needed for efficient metal melting, leading to reduced energy consumption compared to some conventional methods.
- **Better Arc Stability and Control:** Stable DC power results in a more consistent and controllable arc, improving the quality of metallurgical output.
- **Reduced Power Losses:** Optimized designs and harmonic management features lead to lower power losses in the overall system.
- **Environmental Advantages:** EAFs using rectifier transformers enable steel production with 100% scrap metal, which is more energy-efficient and generates fewer greenhouse gases than traditional blast furnace routes.

2. DC TRACTION SYSTEM

- Rectifier transformers are crucial in railway and metro systems for converting AC power from the grid into the DC power needed by traction motors, providing isolation and voltage adaptation for a reliable supply.
- They are essential for handling regenerative braking, where a train's braking energy is fed back into the grid, and ensure efficient, safe operation of electric transport systems.

ROLE AND FUNCTION

- **AC to DC conversion:** The AC power from the national grid is first stepped down by a transformer. This is then converted into a controllable DC supply by a rectifier, which is housed within a combined transformer-rectifier unit in the traction substation.
- **Isolation and voltage adaptation:** The transformer provides electrical isolation and adjusts the voltage to the appropriate level required for the traction motors.
- **Regenerative braking:** In modern systems, the rectifier-inverter combination in the substation can also convert the DC power from a braking train back into AC power, feeding it back into the grid and improving energy efficiency.

BENEFITS

- **Reliable power:** Ensures a steady and reliable DC power supply for the traction motors that drive trains and metros.
- **Efficiency and safety:** Improves the overall efficiency and safety of the traction network by converting power at substations and enabling energy recovery through regenerative braking.
- **Versatility:** Supports a variety of DC traction systems, such as those using

3. ELECTROLYTIC HYDROGEN PRODUCTION

- A rectifier transformer is a crucial component in electrolytic hydrogen production, designed to convert incoming AC power (from the grid or renewables) into the stable, high-current DC power that electrolyzers require to split water into hydrogen and oxygen.

ROLE AND FUNCTION

The primary role of the rectifier transformer unit is to provide a stable, efficient, and controlled DC power supply for optimal electrolyzer function.

- **AC-to-DC Conversion:** It first steps down or up the AC voltage to the required level, and then a connected rectifier (using diodes or thyristors) converts the AC into DC power.
- **Stable and Controlled Power:** It ensures a continuous and stable DC supply, which is essential for the consistent oxidation and reduction reactions at the electrodes, thereby controlling the hydrogen production rate.
- **Harmonic Management:** The design often incorporates multi-pulse rectification (e.g., 12-pulse or 24-pulse) to reduce harmonic content, which can otherwise impact grid quality and electrolyzer efficiency.
- **Continuous Operation:** These systems are designed for 100% continuous duty cycles and high efficiency, often employing advanced cooling systems (oil or water-cooled) to manage heat generated during high-load operations.

BENEFITS

- **Enables Large-Scale Production:** These robust systems are built to handle industrial-scale power requirements, with units rated in hundreds of kA DC output, making large-scale hydrogen generation feasible.
- **Supports Renewable Energy Integration:** They bridge the gap between variable AC power from renewable sources (solar and wind) and the stable DC needs of electrolyzers, often by using advanced power electronics (like IGBT rectifiers) with fast response times to power fluctuations.
- **Enhances Efficiency:** By ensuring a low-ripple DC current, they minimize additional power losses in the electrolyzer, which directly improves the overall energy conversion efficiency from electricity to hydrogen.
- **Protects Equipment:** Integrated voltage regulation, cooling, and protection circuits (overload, short circuit) ensure the safety and longevity of expensive electrolyzer equipment.

COMPARATIVE INSIGHTS

Aspect	Electric Arc Furnace (EAF)	Traction Systems	Electrolytic Hydrogen Production
Nature of Load	Highly fluctuating, short bursts of very high current	Steady DC demand with peaks during acceleration/ braking	Continuous, stable DC demand for long durations
Design Challenges	Withstand harmonics, thermal stress, frequent load changes	Handle regenerative braking, isolation from grid, harmonic mitigation	Ensure low ripple DC, high efficiency, continuous duty
Operational Environment	Harsh industrial (steel plants, high dust, heat)	Transport infrastructure (railway substations, urban metros)	Clean energy plants, often integrated with renewables
Economic Impact	Enables efficient steel recycling and production	Powers electrified transport, reducing fossil fuel dependence	Supports green hydrogen economy, future energy storage
Future Outlook	Demand tied to global steel industry growth	Expanding with railway electrification and urban transit	Rapidly growing with hydrogen economy and decarbonization goals

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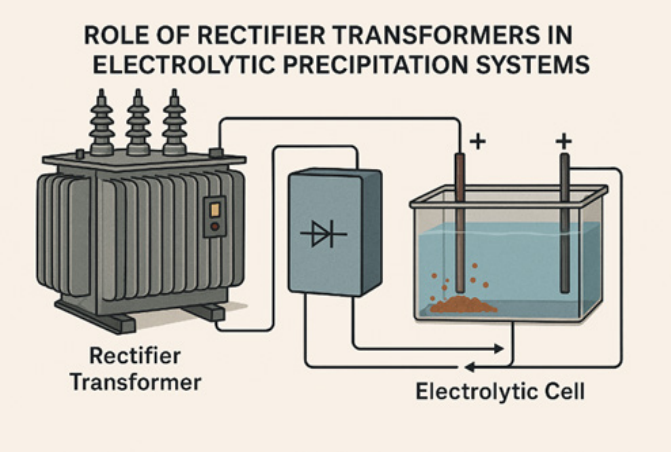
Electrolytic Precipitation Systems



Industrial pollution control relies heavily on electrostatic precipitators (ESPs) for efficient removal of particulate matter from flue gases. At the heart of ESP operation lies the rectifier transformer, which converts low-voltage AC into high-voltage DC, creating the electrostatic field necessary for particle charging and collection. This article examines the design, operation, and significance of rectifier transformers in ESP systems, along with recent advancements that enhance performance and reliability.

Role of Rectifier Transformer in Electrolytic Precipitation System

Power Supply for ESP: Rectifier transformers provide the **high-voltage DC** (typically 50–100 kV) required for electrostatic precipitators to operate.

Voltage Conversion: They step up the incoming **low-voltage AC** (400–480 V) to a much higher level.

Rectification: Convert AC to DC using diode assemblies, ensuring a stable DC output for corona discharge.

Enable Particle Charging: The DC energizes discharge electrodes inside the ESP, creating an electric field that charges dust particles.

Control & Protection: Equipped with voltage regulators, spark detection, and ripple control to maintain efficiency and prevent damage.

Reliability: Ensures continuous and safe operation of ESP systems in power plants, cement, steel, and chemical industries.

PRINCIPLE OF ELETROLYTC PRECIPITATION

1. Ionization of Gas

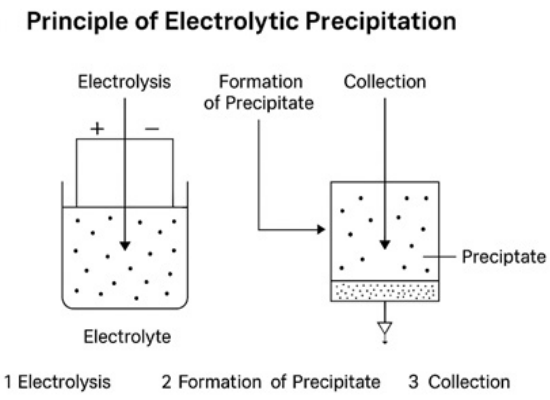
- High-voltage DC (50–100 kV) is applied to discharge electrodes inside the Electrostatic Precipitator (ESP).
- This creates a corona discharge, which ionizes the gas molecules and produces free electrons and ions.

2. Charging of Particles

- Dust particles in the flue gas collide with these ions and acquire a negative or positive charge.
- The efficiency of charging depends on particle size, resistivity, and gas composition.

3. Migration Under Electric Field

- Once charged, particles experience an electrostatic force and migrate toward oppositely charged collection plates.
- The migration velocity is governed by Coulomb's law and depends on the strength



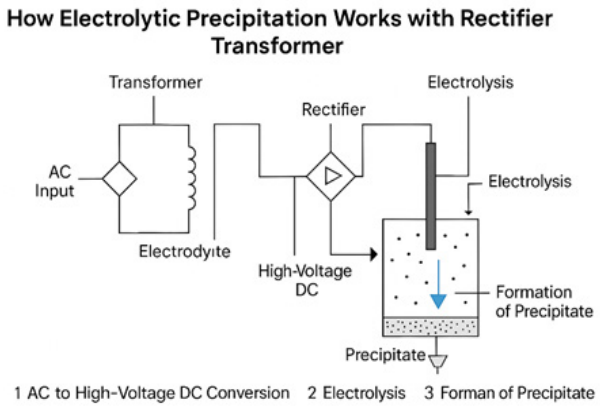
of the electric field.

4. Collection and Removal

- Particles adhere to the collection plates, forming a dust layer.
- Clean gas exits from the ESP.
- Periodic rapping or vibration dislodges the dust into hoppers for disposal.

WORKING OF RECTIFIER TRANSFORMER IN ELECTROLYTIC PRECIPITATION

The process begins with AC power input from the plant supply, which enters the rectifier transformer. Inside the transformer, the voltage is stepped up from low-voltage AC (typically 400–480 V) to a much higher AC voltage. This high-voltage AC is then passed through a rectifier unit, which converts it into high-voltage DC (usually 50–100 kV). This DC output is essential because electrostatic precipitation requires a stable direct current to create a strong electric field inside the precipitator.



Once the HV DC is supplied to the discharge of electrodes inside the ESP, a corona discharge is generated. This discharge ionizes the flue gas molecules, producing ions and electrons that attach to dust particles, giving them an electric charge. These charged particles then migrate toward the collection plates, which are oppositely charged. As the particles accumulate on the plates, clean gas flows out of the system. Finally, the collected dust is periodically removed from the plates by mechanical rapping or vibration, and it falls into hoppers for disposal.

Recent Advancements

1. **High-Frequency Power Supplies (HFPS)**

Traditional transformer-rectifier sets operate at 50/60 Hz, which can cause ripple in the DC output, reducing charging efficiency. High-Frequency Power Supplies operate at several kilohertz, significantly reducing ripple voltage. This results in:

- Improved Particle Charging: More stable corona discharge.
- Better Spark Handling: Faster response to voltage fluctuations.
- Compact Design: Smaller size and weight compared to conventional TR sets.
- Energy Efficiency: Lower power losses and improved control.

2. **Three-Phase Transformer-Rectifier Sets**

Conventional ESP systems often use single-phase TR sets, which produce higher ripple voltage. Three-phase TR sets offer:

- Lower Ripple Voltage: Ensures smoother DC output for consistent corona discharge.
- Higher Corona Power: Improves collection efficiency for low-resistivity dust.
- Cost-Effectiveness: Suitable for large ESP installations in power plants and cement industries.

3. **Digital Controllers**

Modern ESP systems integrate digital control technology for real-time monitoring and optimization:

- Real-Time Monitoring: Tracks voltage, current, and spark rates.
- Fault Diagnostics: Detects insulation failures, diode faults, and oil degradation.
- Energy Optimization: Adjusts voltage automatically to maintain peak efficiency.
- Remote Access: Enables predictive maintenance and reduces downtime.

APPLICATION OF ELETROLYTIC PRECIPITATION

1. Electroplating and Metal Recovery

- **Process**: DC from rectifier transformers drives electrolytic cells where metal ions (e.g., copper, nickel, zinc) are precipitated onto cathodes.
- **Application**: Used in electroplating industries and recovery of valuable metals from waste streams.

2. Water and Wastewater Treatment

- **Process**: Electrolytic precipitation removes heavy metals (like lead, chromium) from industrial effluents by converting them into insoluble forms.
- **Role of Rectifier Transformer**: Provides controlled DC for the electrolytic cells to ensure efficient precipitation.

3. Electrolytic Refining

- **Process:** Purification of metals (e.g., copper refining) where impurities precipitate out during electrolysis.
- **Transformer Role:** Supplies stable DC voltage/current for large-scale refining operations.

4. Chemical Manufacturing

- **Example**: Production of chlorine, caustic soda, and other chemicals via electrolysis.
- **Precipitation Aspect**: Certain by-products or impurities are precipitated during the process.

5. Surface Treatment and Coating

- **Application**: Electrolytic deposition of protective coatings (e.g., anti-corrosion layers).
- **Transformer Role**: Ensures precise DC control for uniform precipitation.

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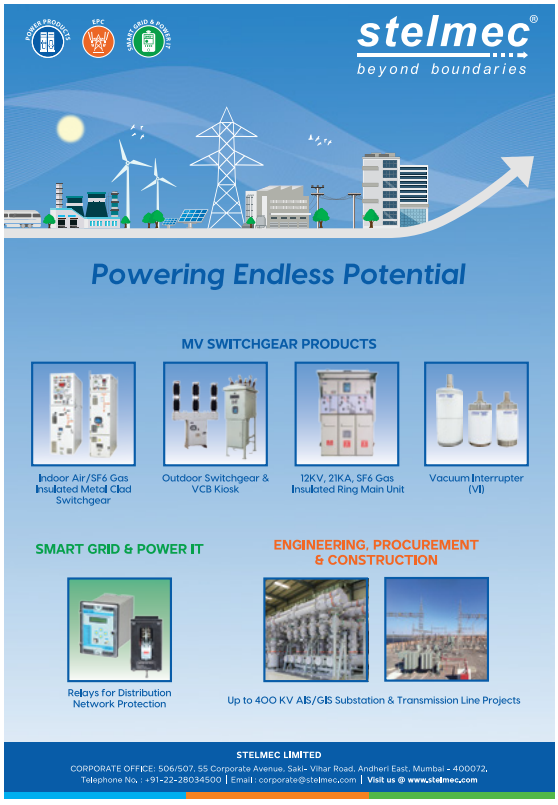
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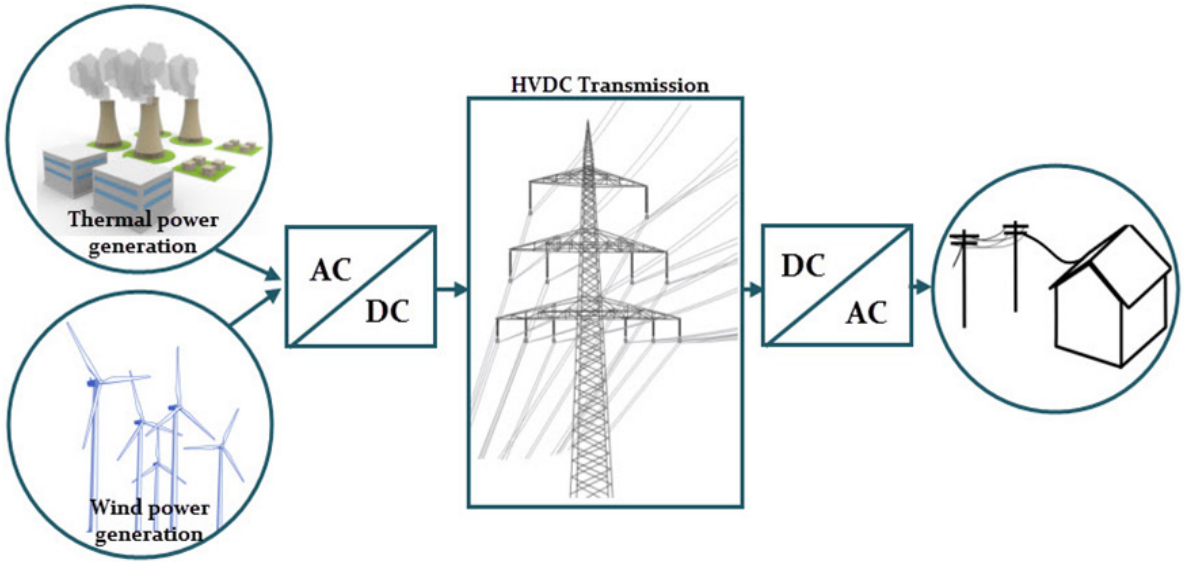
Role of Rectifier Transformers in HVDC Transmission

INTRODUCTION

Rectifier transformers are specialized transformers that convert AC to a regulated DC voltage for high-voltage direct current transmission. They are used to power HVDC converter circuits. They are designed to resist electrical stresses specific to rectification, high harmonic currents, and unbalanced and non-linear loads. Rectifier transformers, which typically feature multi-winding and phase-shift configurations, enable accurate voltage control and harmonic suppression through the use of tap changers.

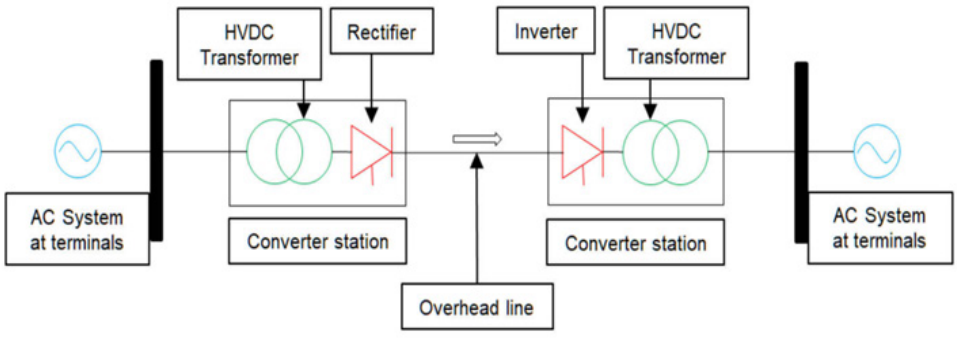
These transformers ensure effective and reliable AC-to-DC conversion for long-distance power transmission in HVDC systems by providing the voltage transformation, electrical isolation, and phase displacement required to feed semiconductor-based rectifier valves. They differ from traditional power transformers due to their strong insulation, cooling, and design for severe electrical and thermal stresses.



Rectifier Transformer: Powering the Future

Rectifier transformers are positioned between the AC transmission network and the power electronic converters (such as thyristor or IGBT valves) at the sending end of an HVDC system. Their main functions include:

- Supplying the correct AC voltage and current to converters for effective rectification and reduce harmonic distortion.
- Providing electrical isolation between the grid and converter equipment.

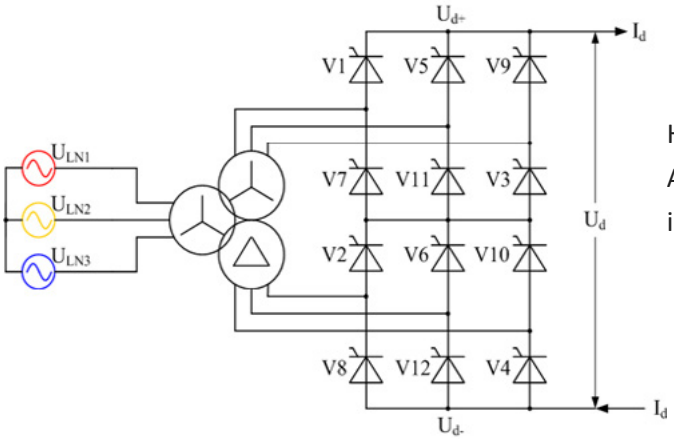


Construction and Design Characteristics

- The winding configurations are often multiphase (e.g., star/star, star/delta) to facilitate the specific converter topology—commonly six-pulse or twelve-pulse systems.
- Special design features include robust insulation systems, enhanced cooling arrangements, and windings capable of handling large short-circuit currents and voltage transients.
- Tap changers are often integrated, allowing for adjustment of the transformer's turns ratio. This provides regulation of the DC output voltage to meet varying load or operational needs. Generally, an OLTC is incorporated for better voltage control.
- Oil or forced air cooling to dissipate heat from harmonic losses and high currents.
- A tank is used for enclosing the transformer parts, filled with insulating oil for electrical insulation and cooling.

HVDC rectifier transformer circuit

The circuit shown is a 12-pulse converter used in high-voltage direct current (HVDC) transmission systems. It functions as a rectifier (converting AC to DC) at the sending end and can operate as an inverter (converting DC to AC) at the receiving end, depending on the control system's firing angle.



The primary purpose of the 12-pulse converter in HVDC systems is to minimize harmonic distortion in the AC current and smooth the DC output voltage, which improves overall power quality and efficiency.

Key Components and Configuration

- **Two Six-Pulse Bridges**: The 12-pulse converter is effectively two standard three-phase, six-pulse bridges connected in series on the DC side. Each bridge contains six switching devices (thyristors or diodes, labeled V1 to V12 in the diagram).

- **Converter Transformer**: A specialized three-phase transformer provides two separate secondary windings with a specific phase shift between their output voltages.
    - One secondary winding is typically star (Y)-connected.
    - The second secondary winding is typically delta (Δ delta)-connected.
- **30-Degree Phase Shift**: The star and delta connections naturally create a 30-degree phase displacement between the AC voltages supplied to the two six-pulse bridges. This is crucial for harmonic cancellation.

Principle of Operation

- **AC-to-DC Conversion**: Each six-pulse bridge rectifies its respective three-phase AC input into a pulsating DC voltage.
- **Harmonic Cancellation**: Due to the 30-degree phase shift between the two AC sources, the harmonic currents generated by one bridge tend to cancel out the harmonics generated by the other when their outputs are combined. This configuration effectively eliminates the dominant 5th, 7th, 17th, and 19th order harmonics, leaving only higher-order harmonics that are easier to filter.
- **Smoother DC Output**: The combination of the two phase-shifted DC outputs results in a DC voltage waveform with 12 pulses per AC cycle, significantly reducing the ripple content compared to a single six-pulse converter.

Role in HVDC Systems

The use of 12-pulse converters is standard practice in conventional (line-commutated) HVDC systems because it offers:

- **Improved Power Quality**: Less harmonic distortion reduces interference with other electrical equipment and communication systems.
- **Higher Efficiency**: A smoother DC waveform minimizes power losses during transmission.
- **Controllability**: When thyristors are used (as indicated by the gate terminals labeled V1-V12), the output DC voltage can be controlled by adjusting the firing angle.

Role of Rectifier Transformer in making HVDC more effective than HVAC:

- **Reduced Losses Over Long Distance**
  HVAC suffers from reactive power losses and skin effect. HVDC eliminates these because DC has no frequency component. The rectifier transformer ensures efficient AC-to-DC conversion, minimizing losses at the interface.
- **Controlled Power Flow**
  HVDC allows precise control of power flow using converters. The rectifier transformer provides the multi-phase input needed for stable and controllable DC output.
- **Harmonic Reduction**
  By creating a 12-pulse configuration, the rectifier transformer reduces harmonics in the DC output, improving efficiency and reducing filtering requirements.

- **Voltage Adaptability**
  HVDC lines often operate at hundreds of kilovolts (e.g., ±500 kV). The rectifier transformer steps up AC voltage to match the converter's DC voltage level, enabling long-distance transmission with lower current and reduced I^2R losses.

The rectifier transformer is the backbone of AC/DC conversion in HVDC systems, enabling high-voltage, low-loss, controllable transmission that HVAC cannot achieve over long distances.

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QUIZ DECEMBER 2025

1. Which type of motor is commonly used in ceiling fans at homes?
   A) Universal Motor
   B) Single-phase AC Induction Motor
   C) DC Shunt Motor
   D) Stepper Motor

2. Which of the following elements cannot be analyzed using Ohm's law?
   A) Capacitors
   B) Inductors
   C) Transistors
   D) Resistance

3. In a three-phase induction motor, if the rotor resistance is increased:
   A) Starting torque decreases
   B) Starting torque increases
   C) Slip at maximum torque decreases
   D) Efficiency improves

4. The efficiency of a transformer is maximum when:
   A) Copper losses = Iron losses
   B) Copper losses > Iron losses
   C) Iron losses = 0
   D) Copper = 0

5. In a circuit breaker, the arc is extinguished by:
   A) Increasing resistance of the arc path
   B) Cooling the arc
   C) Lengthening the arc
   D) All of the above

6. What is the primary characteristic that distinguishes a smart meter from a conventional energy meter?
   A) It can control the generation unit.
   B) It uses two-way communication to exchange data with the utility company.
   C) It is less accurate than a conventional meter.
   D) It is only capable of measuring electricity consumption, not gas.

7. One foot-candle is equal to how many lux?
   A) 1.2 lux
   B) 5.54 lux
   C) 10.76 lux
   D) 100 lux

8. An analog voltmeter works on the principle of
   A) Electromagnetic induction
   B) D'Arsonval movement
   C) Thermal expansion and contraction
   D) Both A & B

9. Solar heat gain/radiation factors are considered for the sizing of:
   A) Copper XLPE cables laid open to air
   B) Outdoor cable trays
   C) Tubular conductors
   D) Transmission lines

10. Famous Indian scientist(s)
    A) C.V. Raman
    B) Homi J. Bhabha
    C) Jagadish Chandra
    D) All of them

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- The Quiz will be open for 10 days from the date of EMAIL.
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- Next days the points will reduce as 90 – 80 – 70 and on 10th day points will be ZERO even if the answer is correct.
- All participants will receive E certificate signed by CEEAMA President with the points earned mentioned on the same.

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Wish you all a better luck this time.

Do spread the word.

October 2025 Quiz Answers

1. C. Both A & B
2. B. 400kV, 132kV, 11kV, 240V, 50Hz.
3. D. All of the above
4. A. Poly Chlorinated Biphenyl
5. B. IEC-62271-1
6. B. Type Tests
7. D. All of the above
8. C. SLD
9. A. All current upto rated load
10. C. Tubular conductors

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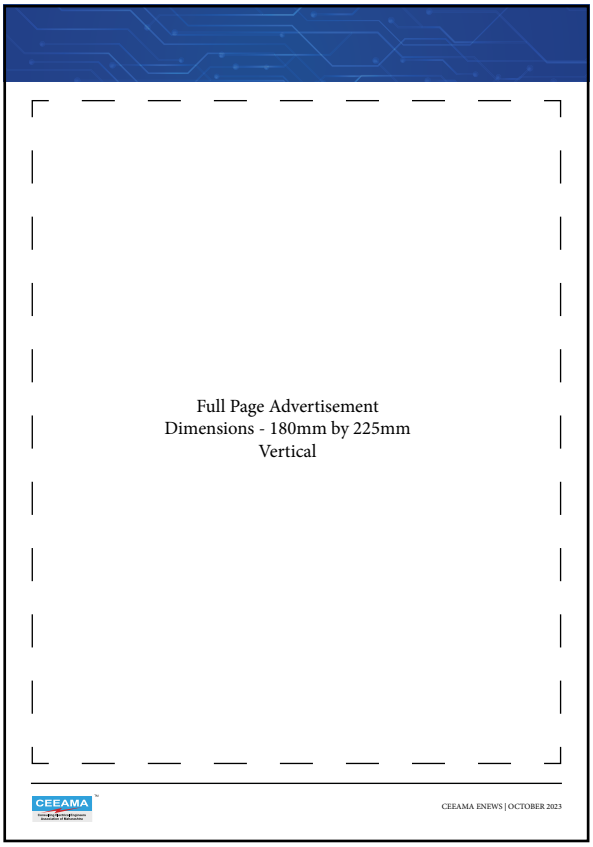

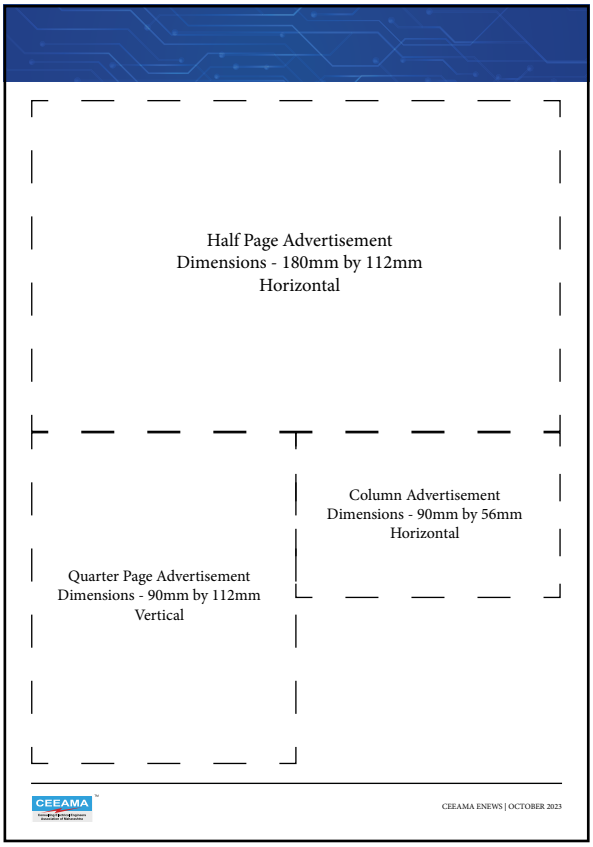

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