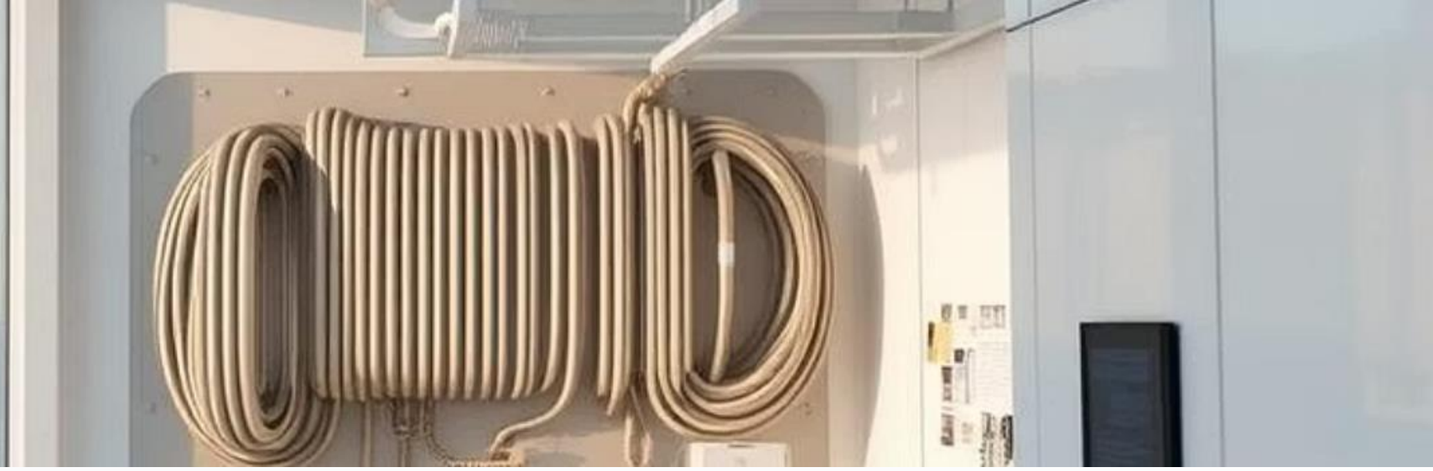
Harmonic Analysis and Distortion in HVDC Systems

Authors: Mohammed Aamir Imran

Affiliation: **Power Grid Corporation Of India Limited Assam**

MD by Mohammed Aamir Imran



Motivation and Overview

Market Growth

Global HVDC market reached $8.7B in 2023, rising fast.

Renewable Integration

Vital for connecting remote renewables like offshore wind farms reaching 110 GW EU target by 2030.

Power Quality

Harmonics threaten grid stability by causing losses and equipment faults.

Topics Covered

Generation, impact, standards like IEEE 519, and mitigation strategies.

HVDC System Basics

LCC Converters

High power, cost effective. Example: Three Gorges-Changzhou ±800 kV, 7.2 GW.

VSC Converters

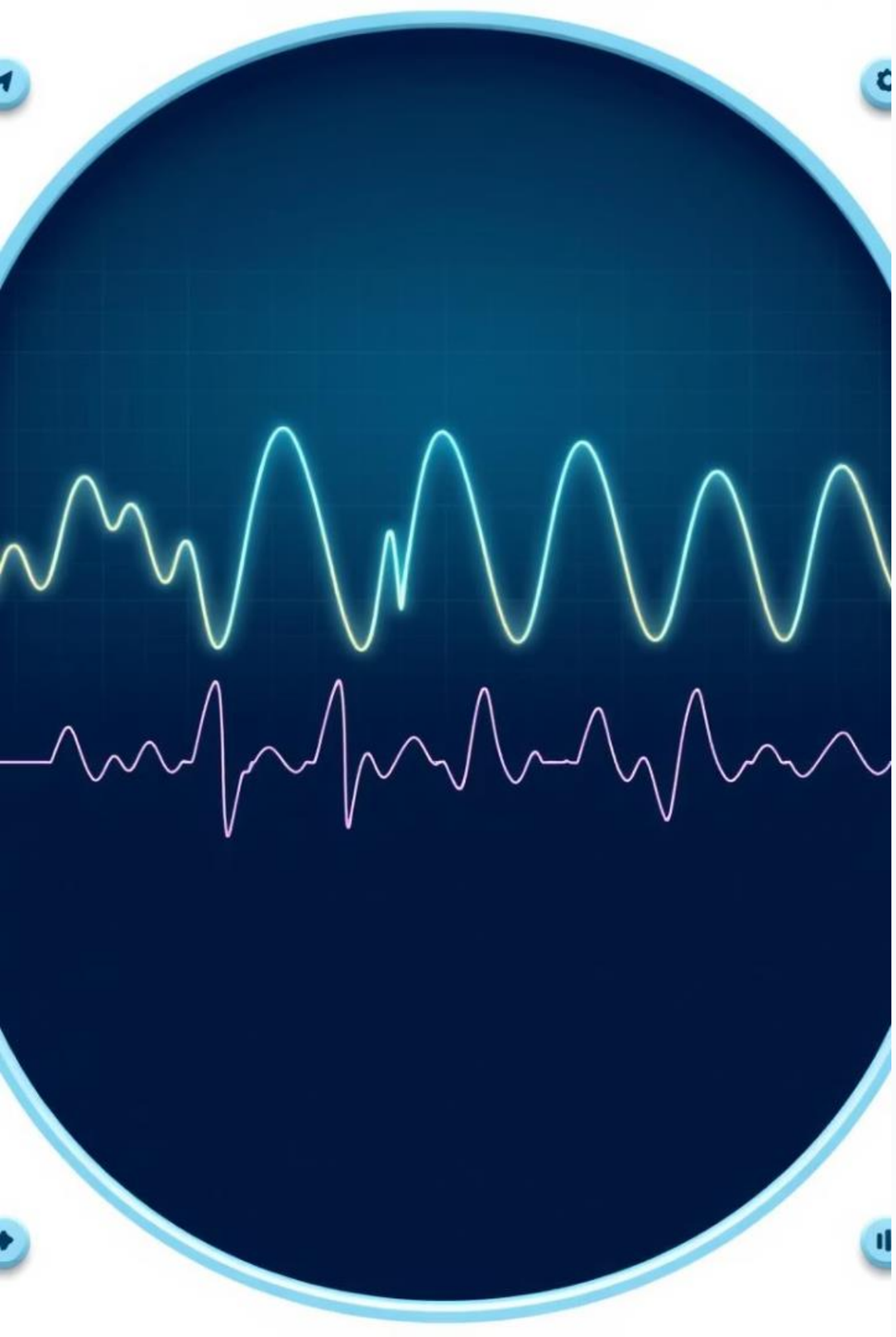
Offers better control, smaller footprint. Example: INELFE France-Spain ±320 kV, 2 GW.

Applications

- Grid interconnections
- Offshore wind integration
- Back-to-back links

Case Study

DolWin3 connects offshore wind to German grid, cutting losses by 60%.



Harmonics and Distortion Metrics

Harmonics Defined

Frequency multiples of 60 Hz causing distortion in the waveform.

Non-Sinusoidal Waveforms

Produced by converter switching, leading to harmonic creation.

6-Pulse Converter

Generates 6n±1 harmonics such as 5th, 7th, 11th, 13th orders.

Total Harmonic Distortion (THD)

Harmonic voltage/current ratio to fundamental. Limits: 5% (voltage), 8% (current).

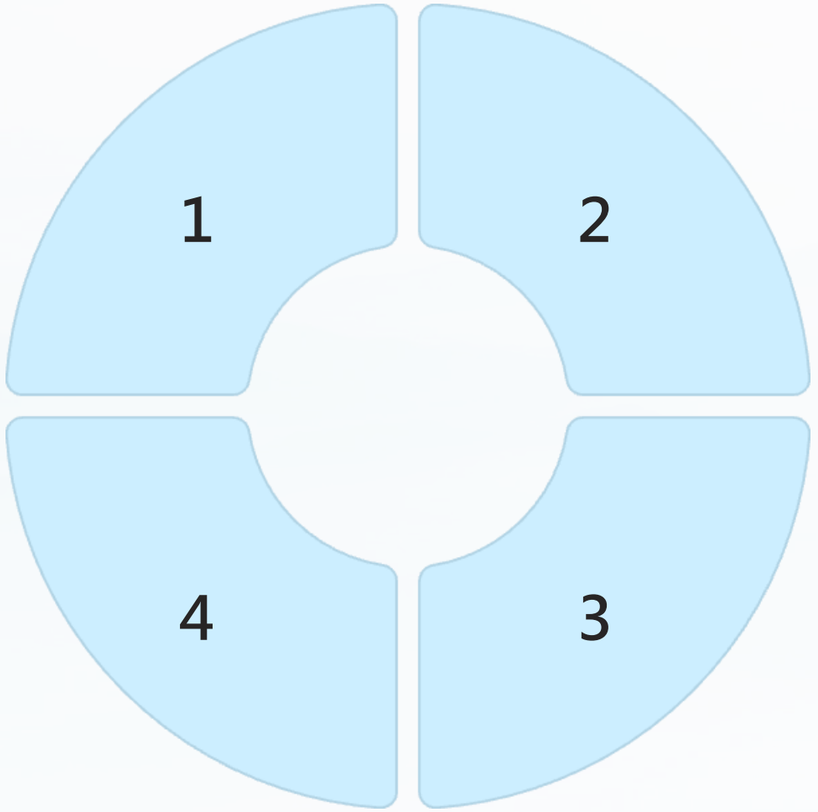
Harmonic Generation in HVDC

LCC Sources

Harmonics arise mainly from AC/DC switching actions.

Filtering Needs

LCC requires more extensive filters than VSC due to harmonic profiles.

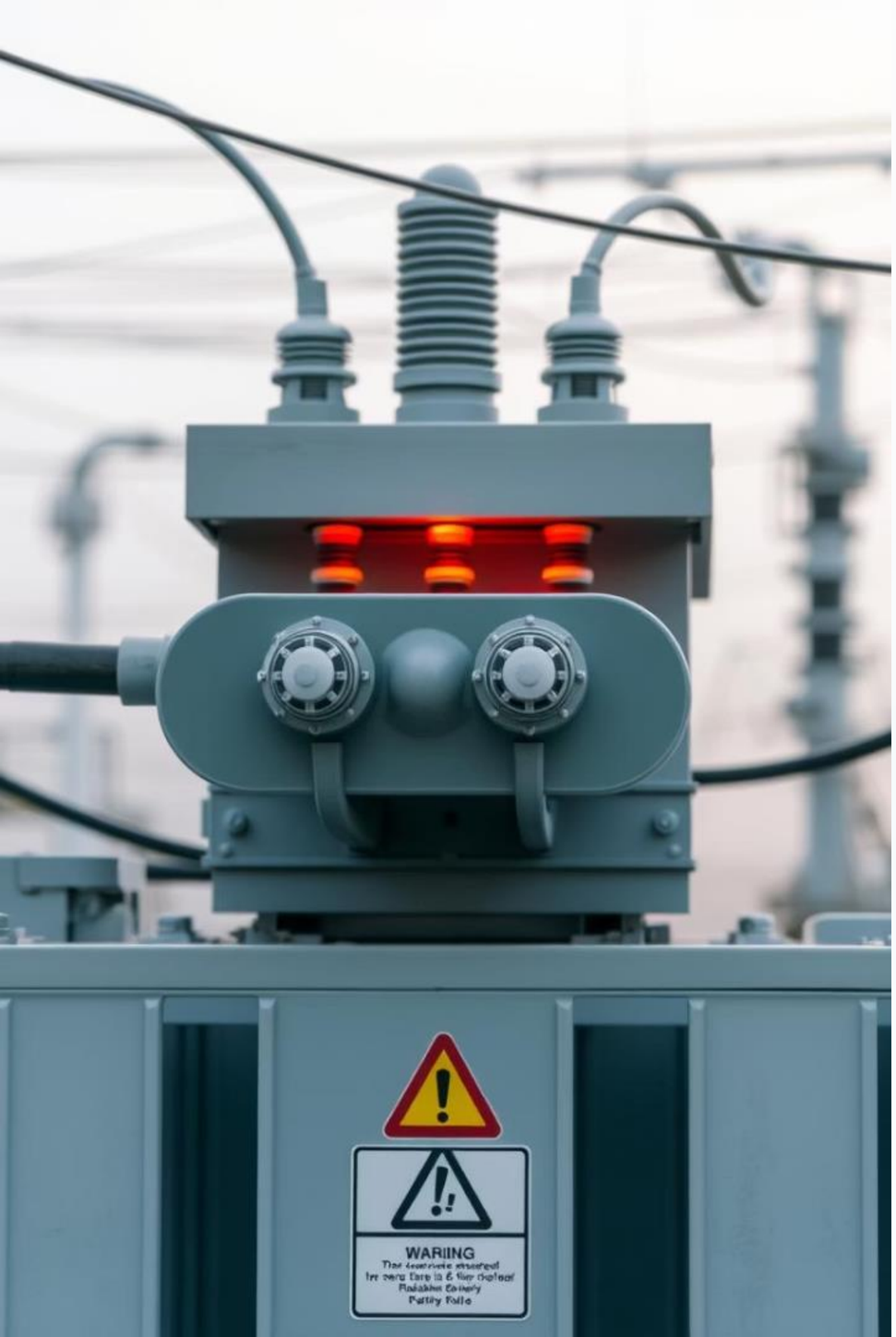


VSC Sources

Harmonics linked to PWM switching above 2 kHz frequency.

Harmonic Spectra

12-pulse LCC and MMC-HVDC systems show differing harmonic patterns.



Impact of Harmonics on Grid

Equipment Overheating

Transformers and motors suffer thermal stress from harmonics.

Resonance Risks

Harmonics amplify at specific frequencies causing instability.

Protection Malfunction

False relay trips and misoperation due to distorted signals.

Communication Noise

Power line communication suffers interference from harmonics.

Capacitor bank failures increase by 20% due to harmonic stress.

Harmonic Standards and Mitigation

1

IEEE 519 Limits

Defines maximum voltage/current distortion at point of common coupling.

2

Passive Filters

Simple LC filters tuned to common harmonics like 5th and 7th.

3

Active Filters

Adaptive compensation yielding up to 98% harmonic reduction.

4

STATCOM Solution

Used in HVDC-VSC for dynamic harmonic mitigation and voltage support.

Summary and Conclusion

Importance

HVDC is vital but introduces harmonic challenges in grids.

Analysis Need

Accurate harmonic study ensures grid stability and equipment safety.

Mitigation

Standards compliance achieved via filters and active compensation.

Future Trends

Wide-bandgap devices improve quality and reduce filter sizes by 40%.