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Advancements in Power Quality Management: Issues and Effective Mitigation Techniques

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Abstract

Power quality (PQ) has emerged as a critical consideration in modern electrical networks due to the growing reliance on sensitive electronic equipment and renewable energy integration. This paper presents an in-depth examination of power quality issues such as voltage sags, swells, harmonic distortion, flicker, and transients, followed by advanced mitigation techniques including active power filters, dynamic voltage restorers, STATCOM devices, and harmonic compensation strategies. By analyzing case studies, technical data, and real-world implementations, this study emphasizes the importance of a systematic approach to PQ management for enhancing reliability, efficiency, and stability of electrical systems.

Keywords: *Power quality, Harmonics, Voltage sag, STATCOM, Active power filter, Mitigation techniques*

INTRODUCTION

Power quality has become a paramount concern in modern electrical distribution and transmission networks. With the penetration of renewable energy sources, nonlinear loads, and distributed generation, the susceptibility of power systems to quality issues has increased substantially. Poor PQ not only affects the performance and lifespan of equipment but also results in significant economic losses. The primary aim of PQ management is to maintain sinusoidal voltage and current waveforms at rated magnitude and frequency.

POWER QUALITY ISSUES

Voltage Sags and Swells

Short-duration variations in RMS voltage caused by faults, motor starting, or sudden load changes.

Harmonic Distortion

Nonlinear loads generate harmonics that distort the waveform, causing overheating and malfunctioning of equipment.

Voltage Flicker

Visible fluctuation in lighting intensity due to rapid voltage changes.

Transients

High-frequency, short-duration surges due to lightning strikes, switching operations, or faults.

Issue	Possible Causes
Voltage Sags and Swells	Short-duration variations in RMS voltage caused by faults, motor starting, or sudden load changes.
Harmonic Distortion	Nonlinear loads generate harmonics that distort the waveform, causing overheating and malfunctioning of equipment.
Voltage Flicker	Visible fluctuation in lighting intensity due to rapid voltage changes.
Transients	High-frequency, short-duration surges due to lightning strikes, switching operations, or faults.

MITIGATION TECHNIQUES

Active Power Filters (Apf)

Used to compensate for harmonics by injecting equal but opposite harmonic currents into the system.

Dynamic Voltage Restorers (Dvr)

Mitigate voltage sags/swells by injecting appropriate voltages through series transformers.

Statcom Devices

Provide dynamic reactive power support to stabilize voltage levels.

Harmonic Compensation

Includes passive filters, tuned LC circuits, and hybrid filtering for targeted harmonic elimination.

CONCLUSION

Maintaining high power quality is essential for ensuring the operational reliability of modern electrical systems. Through the adoption of advanced mitigation devices such as APFs, DVRs, and STATCOMs, utilities can address PQ issues effectively. The

integration of predictive monitoring and adaptive control strategies will further enhance system resilience.

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