Harmonic Analysis

Contents

1. Harmonics in power system.

Harmonics are additional frequencies present in the power system that are integer multiples of the fundamental frequency. These harmonics result from non-linear loads (such as power electronic devices) and can distort voltage and current waveforms.

These harmonics frequently create several complications, some of which are listed below.

Increased Heat in Equipment:

- Transformers, motors, and cables, among other electrical equipment, experience additional heating because of harmonic currents.
- Overheating can lead to reduced efficiency, premature failure, and insulation breakdown.
- Excessive heat might cause safety risks including weak insulation, short circuits or fires.

False Relay Operations:

- Harmonics can trigger false relay operations due to distorted current waveforms.
- This can impact system protection and reliability.

Capacitor Failures:

- Harmonics stress capacitors, reducing their lifespan and causing failures.
- Capacitors are commonly used for power factor correction.

Reduced Power Quality:

- Harmonics distort voltage and current waveforms, affecting overall power quality.
- Reduced power factor or efficiency may indicate the presence of harmonics.
- Misfiring in variable speed drives, and torque pulsations in motors and generators.

2. Harmonic Analysis

Harmonic analysis in power systems involves studying the presence and effects of harmonic components in electrical networks. Harmonic analysis involves measuring the harmonic content of voltages and currents in the power system using instruments such as power quality analyzers. This helps in identifying the amplitude and phase of different harmonic components.

International standards (e.g., IEEE 519, IEC 61000-2-2) define limits for harmonic distortion levels in power systems to ensure reliable operation and compatibility between equipment. Harmonic analysis helps utilities and industries comply with these standards.

Advanced harmonic analysis also involves computer simulations and modeling using software tools like ETAP, SKM, EasyPower. These tools can predict harmonic behavior in complex systems and aid in designing effective mitigation strategies.

Overall, harmonic analysis is crucial for maintaining power quality, ensuring equipment reliability, and complying with regulatory standards in modern electrical power systems.

2.1. Step-by-step approach:

2.1.1. Identify Potential Sources of Harmonics:

Survey and Documentation: Identify all nonlinear loads connected to the power system. These include devices like VFDs, EC Motors, Servers, UPS systems, LED lighting, etc., which are known sources of harmonic currents.

Load Characterization: Understand the operating characteristics of each nonlinear load, such as the magnitude and waveform of current drawn, to estimate potential harmonic contributions.

2.1.2. Measurement of Harmonic Levels:

Install Power Quality Monitoring Equipment: Deploy power quality analyzers or meters at critical points in the power distribution network to measure harmonic voltages and currents.
Data Logging: Collect data over an appropriate period (typically at least a week) to capture variations in harmonic content due to different operating conditions.

2.1.3. Harmonic Data Analysis:

Data Processing: Analyze the collected data to determine the amplitude and phase of harmonic components relative to the fundamental frequency.

Harmonic Spectrum: Plot harmonic spectra (amplitude versus frequency) to identify dominant harmonic orders and their levels.

THD Calculation: Calculate Total Harmonic Distortion (THD) for voltages and currents, which is a measure of the overall harmonic content relative to the fundamental frequency.

2.1.4. Assessment of Compliance with Standards:

Compare with Standards: Evaluate measured harmonic levels against international standards or local regulations (e.g., IEEE 519, IEC 61000-2-2) to determine compliance.

Identify Violations: Identify any harmonic distortion levels that exceed permissible limits and note potential areas of concern.

2.1.5. Simulation and Modeling:

Simulation Tools: Use software tools such as ETAP, SKM, EasyPower etc. for detailed harmonic analysis and prediction.

Scenario Analysis: Model different scenarios (e.g., adding filters, changing system configurations) to assess their impact on harmonic levels and system performance.

2.1.6. Develop Mitigation Strategies:

Filter Design: Design passive harmonic filters based on the harmonic spectrum and identified dominant frequencies.

System Configuration: Consider reconfiguring the power system layout or equipment operation schedules to minimize harmonic interaction.

Optimization: Optimize capacitor and reactor sizing, if used in harmonic filters, to achieve desired attenuation without adversely affecting power factor or system stability.

2.1.7. Implementation and Monitoring:

Implement Solutions: Install and commission chosen mitigation strategies (e.g., filters, system adjustments).

Post-Implementation Verification: Conduct post-implementation measurements to verify the effectiveness of mitigation measures in reducing harmonic levels.

Ongoing Monitoring: Continue to monitor power quality periodically to ensure that harmonic levels remain within acceptable limits, especially as the power system evolves or load characteristics change.

2.1.8. Documentation and Reporting:

Document Findings: Maintain records of harmonic analysis results, measurement data, simulation models, and mitigation strategies implemented.

Reporting: Prepare reports summarizing the harmonic analysis process, findings, compliance status, and recommendations for stakeholders (management, regulatory bodies, etc.).

3. Mitigation

When do harmonics in electrical systems become a significant enough problem that they must be mitigated. Operational problems from electrical harmonics tend to manifest themselves when two conditions are met:

1. Generally, facilities with the fraction of nonlinear loads to total electrical capacity that exceeds 15%.
2. A finite power source at the service or within the facility power distribution system with relatively high source impedance, resulting in greater voltage distortion resulting from the harmonic current flow.

There are various harmonic mitigation methods available to address harmonics in the distribution system. They are all valid solutions depending on circumstances, each with their own benefits and detriments. The primary solutions are harmonic mitigating passive filters.

3.1. Harmonic Filter

In order to design a harmonic filter, information about the local power system, including environmental data, is required. Power system information includes characteristics, such as the nominal line-to-line voltage, typical equipment BIL for the system voltage level, fundamental frequency, system configuration, and impedance of system components. A clear understanding of equipment location (i.e. indoor or outdoor), operating constraints, equipment current duty-cycle, switching operation rates, environmental data (such as ambient temperature and wind loading), harmonic measurements or manufacturer harmonic characteristics, is important to consider before starting the filter design process.

3.1.1. Passive Filter

Passive filters play a crucial role in eliminating harmonics in power systems.

A passive filter component is a combination of capacitors and inductors that are tuned to resonate at a single frequency, or through a band of frequencies. In power systems, passive filters are used to suppress harmonic currents and decrease voltage distortion appearing in sensitive parts of the system.

passive filters are cost-effective but less flexible than active filters. Proper design and placement are essential for optimal results.

3.1.1.1. Objective Definition:

Passive filters work by exhibiting different impedance values at the resonant frequency. A filter connected in series should present high impedance to the harmonic frequency that needs to be blocked. Although a series configuration is possible, it is more common to connect filters in parallel. Such a shunt configuration diverts harmonic currents to ground, and simultaneously provide reactive power, which may be used to correct the power factor. As such, passive shunt filters are designed to be capacitive at the fundamental frequency.

3.1.1.2. Frequency Analysis

Identify the dominant harmonic frequencies in your system.

Filter Type Selection:

Choose from common passive filter types:

- **Single-Tuned Filters:**

These series filters allow a specific frequency to pass while attenuating others.
Composed of an inductor (L) and a capacitor © in a resonant circuit.

- **Double-Tuned Filters:**

Similar to single-tuned filters but with two resonant frequencies.
More effective for multiple harmonics.

3.1.1.3. Component Sizing

Calculate the required inductance (L) and capacitance © values.
Impedance at harmonic frequencies should be high, and at the fundamental frequency, it should be low.

3.1.1.4. Placement

Install the filter close to the harmonic source for effective elimination.

3.1.1.5. Monitoring and Adjustment:

Regularly monitor filter performance and adjust as needed.