Substation Engineering - Surge Arrestors (Part 2 of 2)

Milav Dabgar

Surge Arrestors (Part 2 of 2)

- Advanced Surge Protection
- Metal Oxide Varistors (MOV)
- Selection, Testing, and Maintenance

Agenda

- Recap: SiC vs MOV Technologies
- Metal Oxide Varistors (MOV) Basics
- Gapless Design and V-I Characteristics
- Key Ratings and Selection Criteria
- Installation Practices
- Testing, Monitoring, and Failure Modes

Recap: SiC vs MOV Arresters

- Silicon Carbide (SiC) arresters require series spark gaps to prevent continuous current flow at normal voltages
- SiC blocks have a relatively low non-linear index
- Metal Oxide Varistors (MOV) have highly non-linear characteristics
- MOV arresters eliminate the need for series spark gaps
- MOV arresters provide faster response times to steep-front surges

Metal Oxide Varistors (MOV) Basics

- Primary material is Zinc Oxide (ZnO) with small amounts of other metal oxides (Bismuth, Cobalt, Manganese)
- The microstructure consists of conductive ZnO grains surrounded by highly resistive grain boundaries
- Acts as an excellent insulator at normal power frequency voltages
- Transitions to a highly conductive state during overvoltage events
- Provides seamless transition back to insulating state once the surge passes

Gapless Design and Advantages

- No Spark Gaps: Eliminates problems of gap pitting, moisture ingress, and delayed spark-over
- Continuous Protection: The arrester is permanently connected and responds instantaneously
- Higher Energy Absorption: ZnO blocks can absorb significantly more thermal energy than SiC
- Compact Size: Simplifies substation layout and reduces overall equipment footprint
- Better Pollution Performance: Especially true for polymer-housed ZnO arresters

V-I Characteristics of ZnO

Pre-breakdown region: Very low leakage current (mostly capacitive) at normal voltage

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Knee point: The voltage at which the transition occurs

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Breakdown/Operating region: Current increases by orders of magnitude for a small increase in voltage

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High-current region: Resistance is minimal, discharging the surge energy to the ground

Comparison of Surge Arrester Types

Feature	SiC Arrester	ZnO (MOV) Arrester
Series Gaps	Required	Not Required (Gapless)
Non-linearity	Moderate	Extremely High
Response Time	Slower (due to gap spark-over)	Instantaneous
Leakage Current	Zero (blocked by gap)	Very small (continuous)
Energy Handling	Lower	Higher

Key Ratings of Surge Arresters

- Rated Voltage (Ur): Maximum permissible 10-second power frequency overvoltage
- Maximum Continuous Operating Voltage (MCOV or Uc): The max power frequency voltage the arrester can withstand continuously
- Nominal Discharge Current (In): Peak value of standard lightning impulse (8/20 micro-seconds) used for classification
- Energy Rating (kJ/kV): Capability to dissipate surge energy without thermal runaway

MCOV and Rated Voltage

- MCOV is arguably the most critical parameter for gapless arresters
- MCOV must be strictly greater than the maximum continuous phase-to-ground voltage of the system
- Temporary Overvoltages (TOV) dictate the Rated Voltage (Ur)
- Selection requires balancing protection margin (lower rating) with thermal stability (higher rating)

Arrester Selection Criteria

- Determine the maximum continuous system voltage (to set MCOV)
- Determine maximum Temporary Overvoltage (TOV) magnitude and duration (to set Ur)
- Select the required discharge current class (e.g., 10kA for most transmission systems)
- Calculate the Required Protection Level (LIPL and SIPL) and compare against equipment BIL and BSL
- Ensure adequate protective margin (typically greater than 20% for lightning impulses)

Installation and Location

- Location: Should be located as close as possible to the equipment being protected (typically power transformers)
- Lead Lengths: Keep connecting leads to the line and ground as short and straight as possible
- Inductive Voltage Drop: $L(di/dt)$ in long leads can add significantly to the residual voltage, reducing the protection margin
- Clearances: Ensure adequate phase-to-phase and phase-to-ground clearances

Testing of Surge Arresters

- Routine Tests: Reference voltage test, residual voltage test, partial discharge test
- Type Tests: Operating duty test, TOV test, short-circuit test, weather aging tests
- Field Tests: Insulation resistance (Megger), Third harmonic leakage current measurement
- Thermal Imaging: Infrared thermography to detect localized heating indicating block degradation

Condition Monitoring: Leakage Current

- Gapless arresters conduct a continuous, very small leakage current (usually ¡ 1mA)
- This current has capacitive and resistive components
- Resistive leakage current increases as the ZnO blocks age or absorb moisture
- Third Harmonic Measurement: Used to isolate and measure the resistive component of the leakage current
- Surge Counters: Installed at the base to record the number of surge operations

Failure Modes and Pressure Relief

- Thermal Runaway: Occurs when heat generated exceeds heat dissipation capability (often due to prolonged TOV)
- Moisture Ingress: Leading cause of failure in older porcelain-housed arresters
- Pressure Relief Design: Arresters have directional pressure relief vents to prevent explosive shattering during a short circuit
- Polymer Housings: Preferred modern alternative as they tear open rather than shatter, improving safety

Summary

- MOV technology has made gapless surge arresters the industry standard
- MCOV and Ur are the most critical selection parameters
- Lead lengths must be minimized to ensure effective protection margins
- Resistive leakage current monitoring is the best indicator of arrester health
- Polymer housings provide superior safety during failure modes compared to porcelain

Key Takeaways

- The sharp knee of the ZnO V-I curve enables gapless design
- Arrester MCOV must be safely above the maximum continuous system voltage
- Third harmonic leakage current measurement is essential for predictive maintenance

Next Lecture Preview

- Topic: Insulators, Strings, Clamps, and Connectors (Part 1)
- Types of Substation Insulators
- Porcelain, Glass, and Composite Materials
- Insulator String Arrangements