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Different Types of Transmission Line Insulators: A Complete Classification Guide

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Transmission line insulators are mechanical and electrical components that support overhead conductors on towers and poles while preventing current leakage to earth. Every overhead line above low voltage uses insulators to simultaneously carry conductor weight and tension loads while withstanding line voltage — from 11 kV rural distribution to 1,100 kV ultra-high voltage DC corridors. The five principal types — pin, suspension (disc), strain, line post, and composite long-rod — differ in voltage range, mechanical loading direction, material, and installation position, and selecting the wrong type is a root cause of premature flashover, mechanical failure, and unplanned outages.

Why Insulator Type Selection Matters

Each insulator type is optimized for a specific combination of voltage class, mechanical load direction, and installation position. Mismatches cause:

- **Flashover** — insufficient creepage distance for actual pollution levels (IEC 60815)
- **Mechanical failure** — applying tensile load to a cantilever-designed post insulator, or vice versa
- **Maintenance cost inflation** — wrong material choice for UV, pollution, or temperature environment
- **Standards non-compliance** — ANSI and IEC designs are not interchangeable without adapter hardware

This guide covers each type's design, applicable voltage range, governing standards, and the conditions that make it the right choice.

Type 1: Pin Insulators

Pin insulators are the oldest and simplest overhead line insulator type. A single ceramic or glass body mounts directly onto a metal pin bolted to the crossarm, and the conductor sits in a groove at the top tied with binding wire.

Design and Voltage Range

Pin insulators are practical for **system voltages up to 33 kV**. Above this, the insulation length required for flashover withstand makes the design mechanically unstable — excessive height creates unacceptable cantilever bending stress on the pin at the conductor attachment point.

Standard	Designation	Max System Voltage	Thread Type
IEC 60383	Type P (pin)	36 kV	Metric (M16–M24)
ANSI C29.5 Class 55 (porcelain)		25 kV	1"–8 UN or 1½"–8 UN
ANSI C29.6 Class 55 (wet-process)		25 kV	1"–8 UN or 1½"–8 UN

When to Specify Pin Insulators

- Distribution lines 11–33 kV in IEC markets (MENA, Asia-Pacific, Europe)
- Rural and sub-urban distribution where compact tower design is a priority
- Replacement programs where existing crossarms and pins are standard

See also: [Pin Insulator Types: IEC vs ANSI vs AS Classification](#)

Type 2: Suspension (Disc) Insulators

Suspension insulators — commonly called disc insulators or cap-and-pin insulators — are the standard insulator type for all transmission voltages above 66 kV. Multiple discs are linked by ball-and-socket couplings to form a string; string length determines insulation level.

Design and Voltage Range

Each standard disc (IEC 60305 U70BS profile) contributes approximately 15–16 kV of power-frequency withstand. A 220 kV line typically uses 13–16 discs per string; a 500 kV line uses 24–30 discs. The string hangs vertically from the tower crossarm and supports the conductor in tension — this is purely a **vertical tensile load**, not a cantilever load.

Standard	Disc Type	Mechanical Load (SML)	Coupling
IEC 60305	U70BS (standard)	70 kN	Ball-and-socket 16 mm
IEC 60305	U100BS (heavy duty)	100 kN	Ball-and-socket 16 mm
IEC 60305	U160BS (extra heavy)	160 kN	Ball-and-socket 20 mm
ANSI C29.2 Class 52–3 (porcelain)		36,000 lbf (160 kN)	Ball-and-socket (ANSI dims)

String Configurations

- **I-string (suspension):** Single vertical string at tangent towers — conductor runs straight through; load is conductor weight only
- **V-string:** Two strings forming a V — used at river crossings and high wind locations to limit conductor swing
- **Double I-string:** Two parallel strings — used where single-string failure would cause outage (critical lines)

When to Specify Suspension Discs

- Tangent (intermediate) towers on lines 66 kV and above
- Any application requiring modular voltage upgradeability (add discs when system voltage increases)
- IEC markets standard procurement (U70BS is globally available from multiple qualified manufacturers)

Type 3: Strain Insulators (Dead-End / Tension)

Strain insulators are mechanically identical to suspension discs but are installed **horizontally** at dead-end towers, angle towers, and section points. At these locations, the conductor terminates or changes direction — the insulator must carry the full conductor tension as a direct axial tensile load, which can reach 50–160 kN on bundled EHV conductors.

Design Differences from Suspension Strings

Parameter	Suspension String	Strain String
Orientation	Vertical	Horizontal (or near-horizontal)
Primary load	Conductor weight (vertical)	Conductor tension (axial)
Tower type	Tangent (straight run)	Dead-end, angle, section
Typical SML	70–100 kN	100–160 kN (higher required)
String count	Single or double I	Single, double, or quadruple

When to Specify Strain Insulators

- Dead-end towers at substations and section points
- Angle towers where the line deviation is more than 2–3 degrees
- River crossings and long spans where the conductor tension is significantly higher than on adjacent spans
- Wherever the conductor must be mechanically isolated from the rest of the line (protection scheme requirements)

Type 4: Line Post and Station Post Insulators

Post insulators are cantilever-loaded insulators that hold the conductor rigidly — the conductor is clamped to the top and the insulator body bolts to the structure. Unlike suspension strings, they resist **horizontal forces** (wind, short-circuit electromagnetic forces) as well as vertical loads.

Line Post vs Station Post

Type	Typical Voltage Range	Application	Standard
Line post	15–115 kV	Compact line designs, urban corridors, phase-to-phase spacers	IEC 61952 / ANSI C29.17
Station post	11–800 kV	Substation buswork, disconnect switch supports, instrument transformer pedestals	IEC 60168 / ANSI C29.9

Key Engineering Constraint: Cantilever Strength (SCL)

Post insulators are rated by **Specified Cantilever Load (SCL)** in kN — the maximum horizontal force the insulator can sustain at the conductor attachment point without mechanical failure. This load is determined by:

- Wind load on conductor span (IEC 60826 or national wind standard)
- Short-circuit electromagnetic force (IEC 60865 for buswork)
- Ice load in applicable climates
- Seismic load for substation equipment (IEC 60068–3)

See also: [Line Post Insulator Selection Guide](#) and [Station Post Insulator Selection Guide](#)

Type 5: Composite (Polymer) Long-Rod Insulators

Composite insulators consist of an FRP (fiberglass-reinforced polymer) core rod, rubber sheds (silicone or EPDM), and metal end fittings. They are available in both suspension and dead-end configurations and are a direct replacement for porcelain disc strings at the same mechanical ratings.

Advantages Over Porcelain Disc Strings

Property	Porcelain Disc String	Composite Long-Rod
Weight (220 kV string)	~45 kg	~4 kg
Pollution performance	Good (smooth glazed surface)	Excellent (hydrophobic silicone)
Vandalism resistance	Vulnerable (disc shattering)	High (no brittle components)
Inspection method	Visual + zero-sequence detection	Visual (no internal defect issue)
End-of-life	Disc replacement (modular)	Full replacement (not modular)

When to Specify Composite Insulators

- High-pollution zones (coastal, industrial, desert with salt deposits) — silicone hydrophobicity significantly outperforms porcelain in IEC 60815 SPS c/d environments
- Lines subject to vandalism (composite does not shatter like glass discs)
- Tower weight-sensitive designs (composite is 80–90% lighter than equivalent porcelain string)
- Lines in seismic zones (lower weight reduces seismic load on tower)

Governing standard: IEC 61109 (composite suspension and tension), IEC 61952 (composite line post).

Insulator Type Selection by Voltage and Application

System Voltage	Tangent Tower	Dead-End / Angle Tower	Substation
≤33 kV	Pin insulator	Strain disc string (3–5 discs)	Station post
33–66 kV	Line post or suspension string	Strain disc string (5–8 discs)	Station post
110–132 kV	Suspension disc string (8–10 discs)	Strain disc string (8–10 discs)	Station post
220 kV	Suspension disc string (13–16 discs)	Strain disc string (13–16 discs)	Station post (multi-unit)
400–500 kV	Suspension disc string (24–28 discs)	Strain disc string (24–28 discs)	Station post (multi-unit)

Disc counts assume IEC 60815 SPS b (medium pollution). Add 2–4 discs for SPS c/d, or specify composite insulators for equivalent creepage with lower weight.

Material Comparison: Porcelain vs Glass vs Composite

Property	Porcelain	Toughened Glass	Composite (Silicone)
Applicable standards	IEC 60305, ANSI C29.2	IEC 60305	IEC 61109, IEC 61952
Pollution performance	Good	Good	Excellent (hydrophobic)
Failure mode detection	Difficult (internal cracks)	Self-revealing (shatters visibly)	Visual inspection only
Weight	High	High	Low (10% of glass/porcelain)
Vandalism risk	Medium	High (gunshot shattering)	Low

Property	Porcelain	Toughened Glass	Composite (Silicone)
UV/weathering	Excellent	Excellent	Good (silicone > EPDM)
Typical service life	40—60 years	40—60 years	25—40 years

Creepage Distance and Pollution Severity

Regardless of insulator type, creepage distance must be calculated from actual site pollution severity per [IEC 60815](#). The standard defines four Specific Pollution Severity (SPS) levels, each with a required minimum specific creepage (mm per kV of Um):

SPS Level	Environment	Min. Specific Creepage (mm/kV)	Unified Specific Creepage (mm/kV)
a (light)	Rural, desert (low conductivity dust)	16	20
b (medium)	Agricultural, light industrial	20	25
c (heavy)	Coastal, heavy industrial	25	31
d (very heavy)	Marine, chemical/cement plants	31	35

MENA transmission lines frequently fall in SPS c or d due to coastal salt spray, desert dust with high conductivity, and proximity to petrochemical facilities. Always verify pollution severity from site measurements, not assumed defaults.

Frequently Asked Questions

What is the most common type of insulator used on transmission lines?

Suspension (disc) insulators are the most common type on high-voltage transmission lines above 66 kV. They are used in strings of multiple discs to achieve the required insulation level, and their modular design allows easy voltage upgrades by adding discs without replacing hardware.

What is the difference between a suspension insulator and a strain insulator?

Suspension insulators support conductors vertically at intermediate towers where the conductor runs straight through. Strain insulators (also called tension insulators) are installed at dead-end towers, angle towers, or section points where the conductor terminates or changes direction — they carry the full horizontal tension load of the conductor span.

At what voltage should I switch from pin insulators to suspension insulators?

Pin insulators are practical up to 33 kV system voltage. Above 33 kV, the required creepage distance makes pin designs mechanically unviable (excessive height and cantilever stress).

Suspension disc strings are the standard choice from 66 kV upward. For 33–66 kV, line post insulators offer a good intermediate solution combining post rigidity with reasonable insulation levels.

Can composite insulators replace porcelain disc strings on existing towers?

Yes, composite long-rod insulators are a direct mechanical replacement for porcelain disc strings. They use the same end fittings (ball-and-socket per IEC 60305) and can be specified to equivalent mechanical loads (SML). The main engineering checks are: end fitting dimensions, dry arcing distance, and creepage — most utilities run a parallel installation pilot before full cutover.

How many discs are needed for a 220 kV suspension string?

A typical 220 kV suspension string uses 13–16 standard discs (IEC 60305 Type U70BS or equivalent, 146 mm spacing). The exact count depends on pollution severity per IEC 60815: light pollution (SPS a) needs ~13 discs for 2,800 mm dry arc; heavy pollution (SPS d) may need 16+ discs to achieve the required specific creepage of 31–35 mm/kV. Always calculate from the IEC 60815 site pollution assessment, not nominal voltage alone.

Related Resources

- [Pin Insulator Types: IEC vs ANSI vs AS Classification](#)
- [Line Post Insulator Selection Guide](#)
- [Station Post Insulator Selection Guide](#)
- [Porcelain vs Composite Insulators: Material Comparison](#)
- [Suspension Insulator Selection Guide: Disc Count, SML & Creepage](#)
- [IEC 60815 Pollution Severity and Creepage Distance Guide](#)
- [ANSI C29.7 vs IEC 60383: Standards Comparison](#)

Need Insulators for a Transmission Line Project?

Vuulcan Insulators supplies suspension discs, strain strings, line post, station post, and composite insulators for HV and EHV projects across MENA and Asia-Pacific. Our technical team can advise on string design, pollution severity assessment, and IEC/ANSI compliance documentation.

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TECHNICAL REFERENCE

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