INFOGRAPHIC

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MODERN SUBSTATIONS

SPACE, THERMAL STRESS, AND GROWING DEMAND ARE REDEFINING SUBSTATION DESIGN

79% BY 2050

THE EVOLVING SUBSTATION LANDSCAPE

MODERN SUBSTATIONS DEMAND SMALLER, SMARTER, HIGHER-PERFORMING COMPONENTS

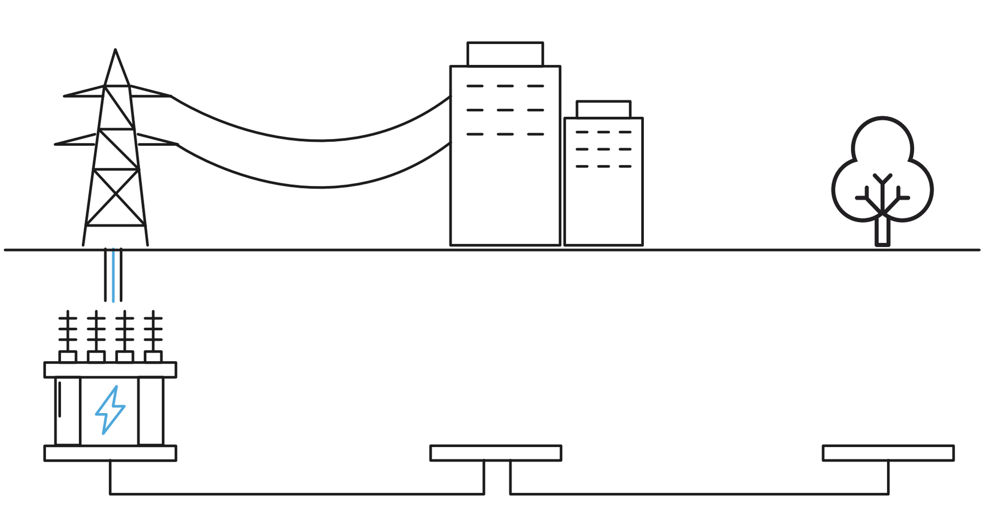
Global energy demand is set to surge **79% by 2050**, driven by rapid adoption of **EVs,** growth of AI-powered infrastructure, and widespread **electrification**. Utilities face growing **pressure to modernize critical grid infrastructure, particularly substations,** which are increasingly moving underground.

Underground substations offer enhanced resilience against severe weather and catastrophic events, increased security, and valuable freed-up space in urban areas. By 2040, nearly 50% of new distribution substations could be underground – creating **unique engineering challenges** due to stricter **space constraints** and harsher **thermal conditions.**

Meeting these challenges requires components that are compact, resilient, and engineered for high performance – especially **capacitors.**

PRESSURE POINTS	MODERN SUBSTATION CHALLENGES
79% rise in energy demand by 2050	Need for significantly higher power-handling capacities and scalability
Rapid EV adoption	Increased demand for rapid voltage stabilization and peak load handling
Integration of AI-driven technologies & data centers	Need for continuous, reliable, high-quality power delivery
Widespread electrification	Strain on aging infrastructure; demands for efficient power management
Severe weather and catastrophic event resilience	Need for protected, underground installations
Enhanced security & reliability expectations	Compact, secure, and accessible components for underground environments
Urban space constraints	Highly compact, modular equipment due to limited installation space
Harsher thermal environments underground	Components capable of reliable operation at extreme temperatures (≥135°C)
High-frequency switching in advanced transformers	Capacitors that handle rapid cycling without degradation
Maintenance costs and operational disruptions	Capacitors with long lifespans requiring minimal maintenance and few replacements

Modern substations need capacitors specifically engineered to **withstand high-frequency switching, extreme temperature fluctuations,** and the **rigorous operating conditions** of next-generation substation technologies like solid-state transformers.



CAPACITORS: THE BACKBONE OF MODERN SUBSTATIONS

MODERN SUBSTATIONS RELY ON CAPACITORS TO STABILIZE VOLTAGE, FILTER HARMONICS, AND DELIVER REACTIVE POWER

Capacitors are essential to the performance and stability of power grid infrastructure. They regulate voltage, supply reactive power, and filter harmonics – functions that are especially critical within substations. **Capacitor banks play a central role** in maintaining voltage levels and delivering reactive power support to ensure reliable, efficient grid operation.

FUNCTION	BENEFIT
Energy Storage	Store and release energy to stabilize voltage during load fluctuations or renewable surges
Reactive Power Compensation	Maintains steady bus voltage and corrects power factor, reducing losses and preventing overload
Power Factor Correction	Improves energy efficiency by offsetting inductive loads, minimizing waste and lowering utility costs
Harmonic Filtering	Suppresses harmonics, improving power quality and equipment protection
Voltage Surge Protection	Protects equipment from sudden voltage spikes, ensuring reliability and the safety of substations
System Flexibility	Enables scalable, modular capacitor banks to adapt to changing substation loads and configurations
Reduced Maintenance	Extends component lifespan and reduces replacement needs – critical for underground & remote substations

Reliability under electrical and thermal stress is non-negotiable. Substation capacitors must endure voltage surges, switching spikes, rapid load changes, and sustained >135°C thermal environments—**without loss of performance or stability**

BOPP-BASED **CAPACITORS** ARE FALLING SHORT

THE BOPP BOTTLENECK

MODERN DESIGNS DEMAND MORE THAN LEGACY CAPACITORS CAN DELIVER

Standard **BOPP-based capacitors are falling short.** As substations move underground and shift toward compact, high-efficiency designs, they can't keep pace. High heat, fast switching, and limited space expose critical weaknesses in BOPP: **thermal derating, dimensional instability,** and **premature failure.**

BOPP capacitors have become a critical bottleneck—limiting reliability, efficiency, and design flexibility in modern substation environments.

SUBSTATION CONDITIONS	BOPP LIMITATION	ENGINEERING CHALLENGE
Elevated Ambient Temperatures	Derates above 85°C; risk of thermal breakdown	Requires overengineering or active cooling to prevent failure in compact, high-heat environments
Underground or Enclosed Installation	Shrinks and warps under prolonged heat exposure	Dimensional instability, jeopardizing reliability in underground or hard to service areas
High-Frequency Switching	Increased dielectric losses and self-heating	Limits performance in fast-switching applications; higher energy waste and risk of overheating
Compact Substation Designs	Requires more volume to achieve capacitance	Occupies too much space; not viable for modular or space-constrained layouts
Long Duty Cycles & 24/7 Operation	Shorter lifespan under sustained thermal/electrical stress	Leads to more frequent maintenance, higher total cost of ownership, and reduced uptime
Modernization Pressure	Incompatible with next-gen form factors or advanced transformers	Limits adoption of solid-state designs and modular upgrades critical to grid modernization

Modern substations demand advanced capacitors that perform under pressure and can withstand extreme heat, handle high-frequency switching, and maintain stability in compact environments. **NanoPlex based capacitors are engineered from the ground up** to meet these exacting requirements, delivering the thermal resilience, electrical performance, and design flexibility modern substations require

OPERATATES UP TO **5X** LONGER

THE PEAK NANOPLEX™ ADVANTAGE

ENGINEERED FOR HIGH HEAT, FAST SWITCHING, AND COMPACT SUBSTATION DESIGNS

Modern substations demand capacitors that perform beyond the limits of traditional BOPP films. Capacitor OEMs need a dielectric film that performs at higher temperatures, faster switching speeds, and better form factors – without sacrificing reliability or performance.

Next-generation NanoPlex film delivers. Engineered for thermal stability, high-frequency switching, and modular integration, NanoPlex operators reliably up to 135 °C, lasts up to 5x longer, and delivers 4x the energy density of standard BOPP — enabling smaller, cooler, longer-lasting capacitors that are drop-in compatible with existing designs. With U.S. based manufacturing and an allied-sourced supply chain, NanoPlex enables substations to upgrade without compromise or risk.

ADVANTAGE OF NANOPLEX CAPACITORS VS. BOPP CAPACITORS

FEATURE	NANOPLEX	BOPP
Max Operating Temp	Operates reliably up to **135 °C without derating**	Up to 85 °C; derating required in high-heat conditions
Thermal Stability	**No film shrinkage** or degradation **at 135 °C**	Shrinks/degrades under elevated temperatures
Operational Lifespan	**Up to 5x longer life** under continuous thermal & load stress	Shorter lifespan under substation duty cycles
Dissipation Factor	**50% lower energy losses;** reduced self-heating	Higher losses, more heat generation
Energy Density	Up to **4x energy storage** per unit volume	Lower density; requires more space for desired capacitance
Size & Weight	**50% smaller, 30% lighter** – ideal for tight spaces & retrofits	Bulky form factors limit installation options in compact substations
Design Compatibility	**Plug-and-play with existing designs & equipment,** including metallization & winding	Incompatible with modern substation upgrade paths
Manufacturing	**100% U.S. engineered and manufactured**	80% of BOPP film sourced overseas, 70% from China
Supply Chain	**100% allied-sourced and geopolitically insulated**	Subject to geopolitical risk and sourcing delays

NanoPlex enables utility engineers with capacitors that can operate reliably in extreme environments, tolerate high stress, and fit within increasingly compact substation designs.

70% OF GRID IS 25 YEARS OLD

ENGINEERED TO OUTPERFORM

NANOPLEX IS PURPOSE-BUILT FOR THE HEAT, LOAD, AND LAYOUT DEMANDS OF MODERN SUBSTATIONS

NanoPlex isn't just a better film – it's a generational leap forward for substation capacitor performance. It enables substations to meet the demands of underground installation, modularization, and solid-state integration – without compromising on reliability, thermal tolerance, or lifecycle performance.

Thermal Resilience
Operates reliably in high-heat environments where standard capacitors degrade

Compact & Modular
Enables smaller capacitor banks for tight footprint—ideal for underground & urban substations

Extended Operational Life
5× longer service life minimizes maintenance & reduces replacement cycles

Efficient Power Regulation
Supports stable voltage and reactive power delivery in high-frequency switching environments

High Energy Density
Stores 4x the energy per unit volume—maximizing performance in limited space

Grid Modernization Ready
Built for solid-state transformers, hybrid PFC, and next-gen substation tech

NanoPlex film powers the next generation of substations – where space is tight, temperatures are high, and performance and reliability must never be compromised.

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