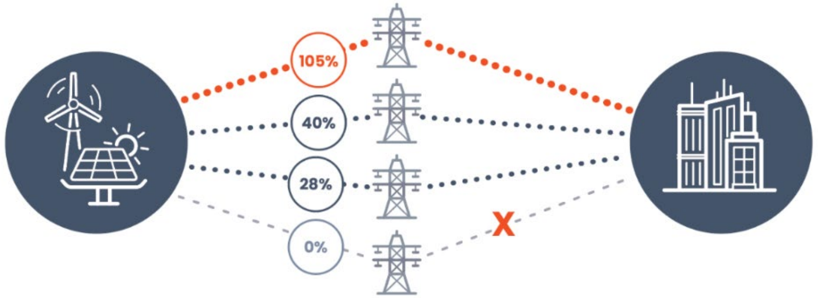
SmartValve for Series Compensation without SSR

April 2025

Contents

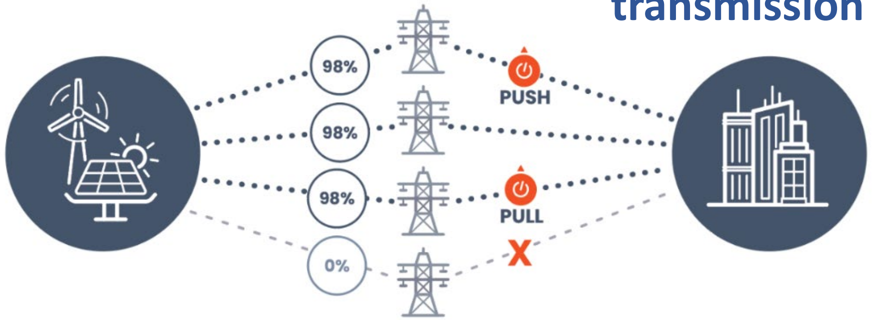
Advanced Power Flow Control (APFC) boosts transfer capacity across a set of lines

SmartValve
Modular SSSC



Before SmartValve

+50% in firm transmission capacity



After SmartValve

SSSC: Static Series Synchronous Compensator

Smart Wires' APFC projects with 25+ utilities across the world

Nearly 4 Gigawatts of firm transmission capacity unlocked, delivering $1.6 billion savings to consumers

North America

- Multiple projects supporting generation and data center interconnection approved in New England, California, and New York
- Deployed at 345 kV and 230 kV to unlock 400 MW of firm capacity in NY and GA

PG&E | Georgia Power | Central Hudson

Europe

- 2 GW firm capacity unlocked to reliably enable greater on-shore and off-shore wind penetration
- NGET using APFC across seven 275 kV and 400 kV circuits, delivering £387M savings for consumers vs. alternative solutions

nationalgrid | UK Power Networks | ipto

Latin America

- Over 1.1 GW firm capacity unlocked to support demand increase and improve reliability, reducing need for new infrastructure in urban areas
- Projects with five utilities across eighteen 110, 138 and 220 kV circuits

isa | epm | enlaza

Australia

- Over 185 MW firm capacity unlocked, improving reliability and transfer of electricity between states
- Projects with three utilities across circuits from 132 kV to 330 kV, delivering over AUD 268 M in savings vs. alternative solutions

Transgrid | AusNet services | ElectraNet

Tech Hub & HQ: North Carolina, USA

ISO 9001 Manufacturing: St. Petersburg, Florida

Global Presence: Additional offices in Ireland, Colombia, Australia and a global workforce

Key Partners: Mitsubishi, Infineon, Jabil, Powersoft 19

Operational Record: 3,200+ device-years of operation

Intellectual Property: 100+ patents, know-how and technology stack

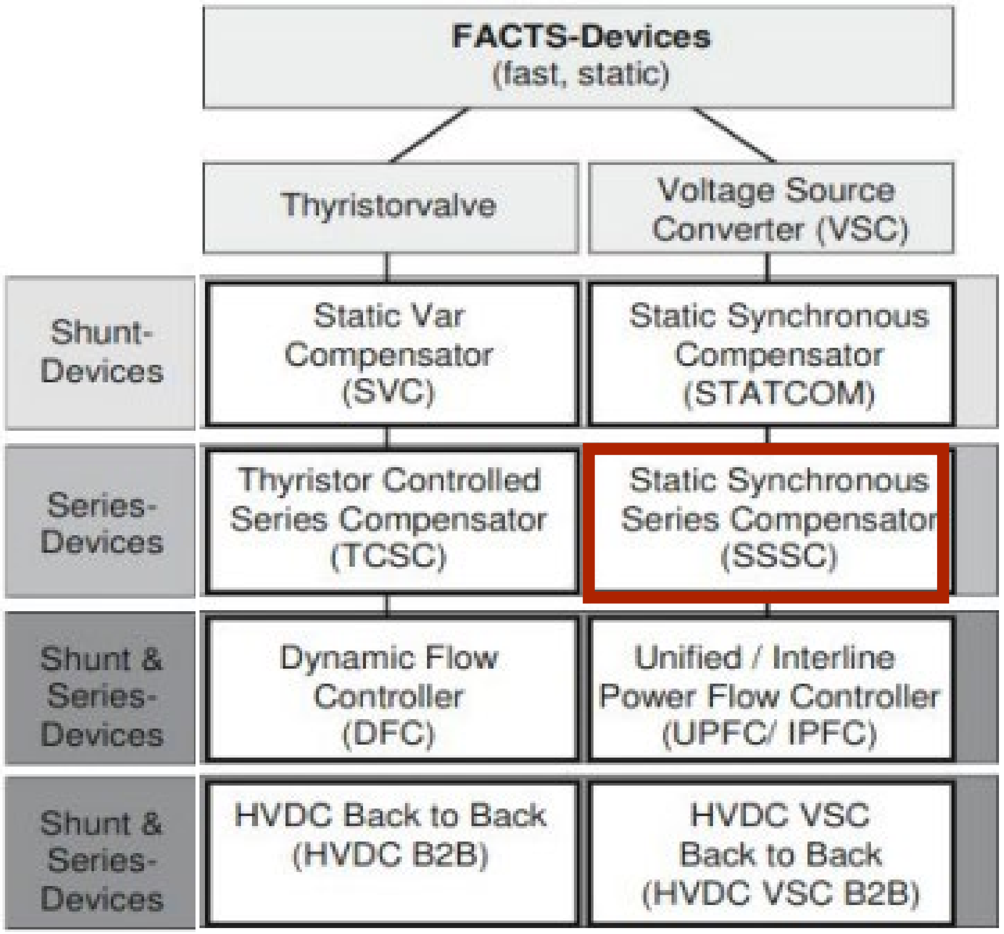
PGRR 120 Comments

- Smart Wires supports the Lone Star and Splight comments detailing that certain grid enhancing technologies, including M-SSSC like SmartValve, can provide series compensation while mitigating risk of Subsynchronous Oscillation (SSO) and Subsynchronous Resonance (SSR), and that a blanket ban by ERCOT on interconnection of series-compensated lines is not a prudent solution.
- Specifically, Smart Wires proposes modifying the proposed PGRR 120 language to include valid exceptions for generators and allow Transmission Service Providers (TSPs) to propose M-SSSC as an option for SSO mitigation

Product details

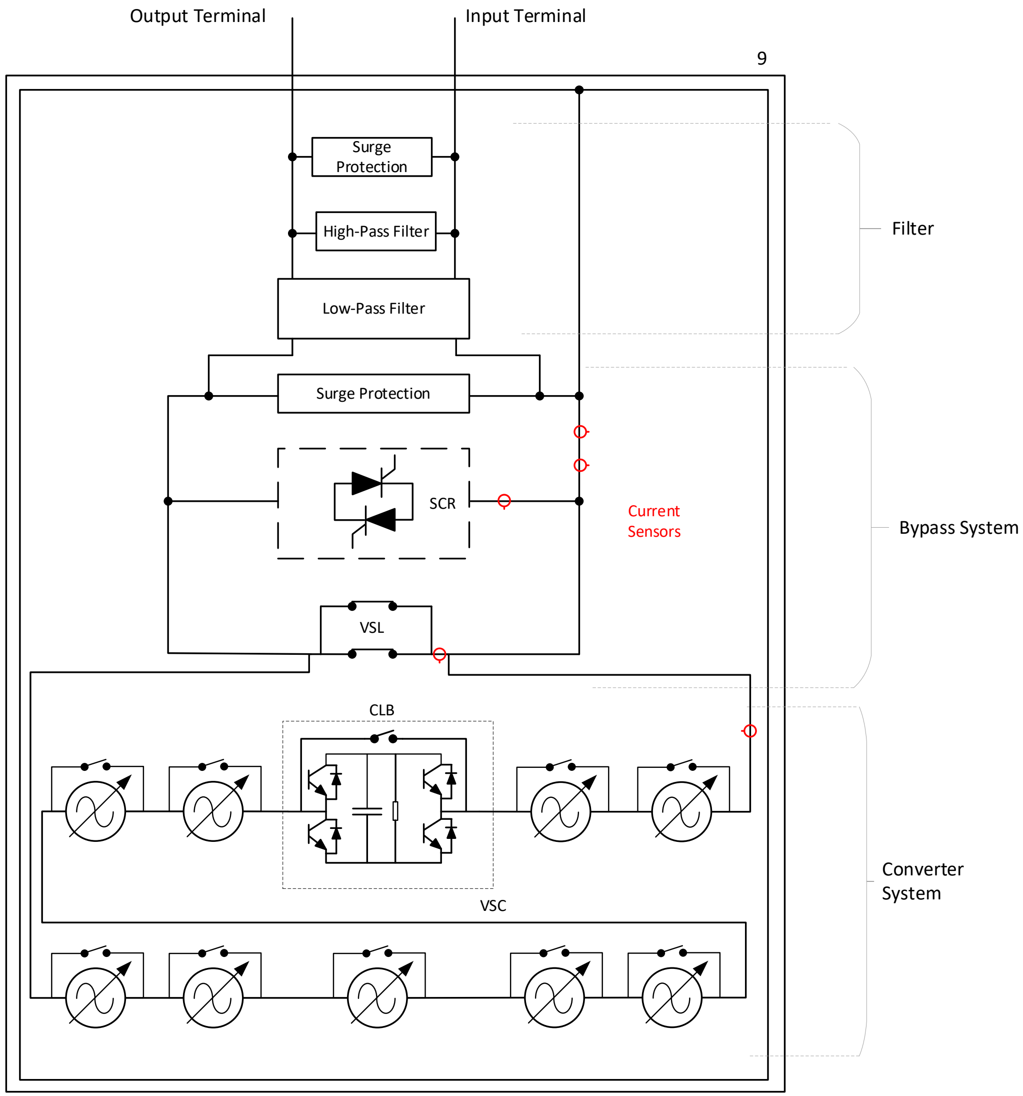
The SmartValve: Leading APFC Solution

- Transformerless, series-connected FACTS device that employs VSC technology
- Capable of controlling line reactance in real-time
- Modular design for flexible and scalable installations
- Voltage agnostic and re-deployable
- Quick to deliver and deploy
- Integrated fast-acting bypass
- High reliability and redundancy



FACTS: Flexible AC Transmission System, VSC: Voltage Source Converter

SmartValve single line diagram



SmartValve 10-1800 Single-Line Diagram

SmartValve is a **Normally Closed** device that harvests all power from the line to operate the control and communication circuits and senses line current for control and fault-protection purposes.

Filter Capabilities

- The high-pass filter allows the passage of high frequency transients.
- The low-pass filters allow the power line frequency to enter the SmartValve.

Bypass Capabilities

- The vacuum switch links (VSLs) primarily conduct current during steady-state conditions.
- The silicon-controlled rectifiers (SCRs) primarily conduct current during grid faults (e.g. a fault on the line connected to the SmartValve).

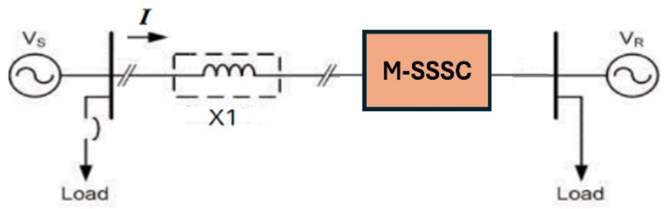
Converter Capabilities

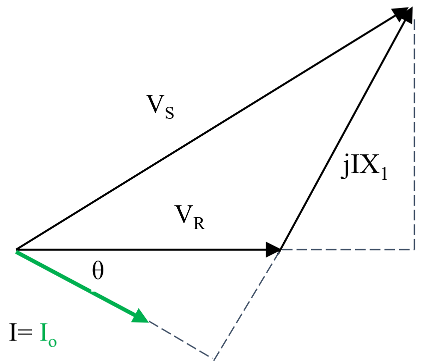
- The core components of each Voltage-Sourced Converter (VSC) are four semiconductor switches and the DC Link capacitor.

Principles of operation

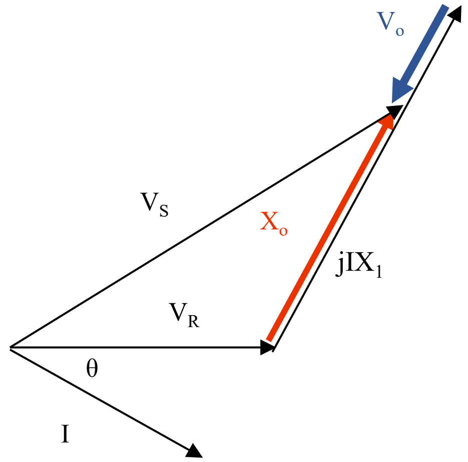
SmartValve Operating Characteristics

- Series voltage source operating at line potential independent of line current
- SmartValve injects voltage with an angle of approx. 90° leading/lagging the line current
- This voltage injection emulates a reactance change in the line
- Can operate as a continuously variable series reactance, both capacitive or inductive

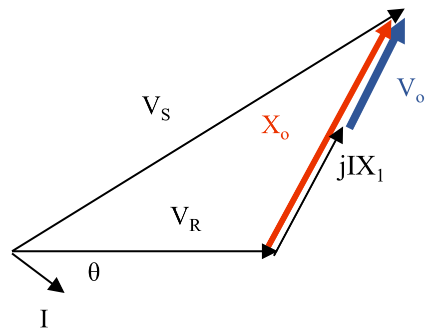




No Compensation



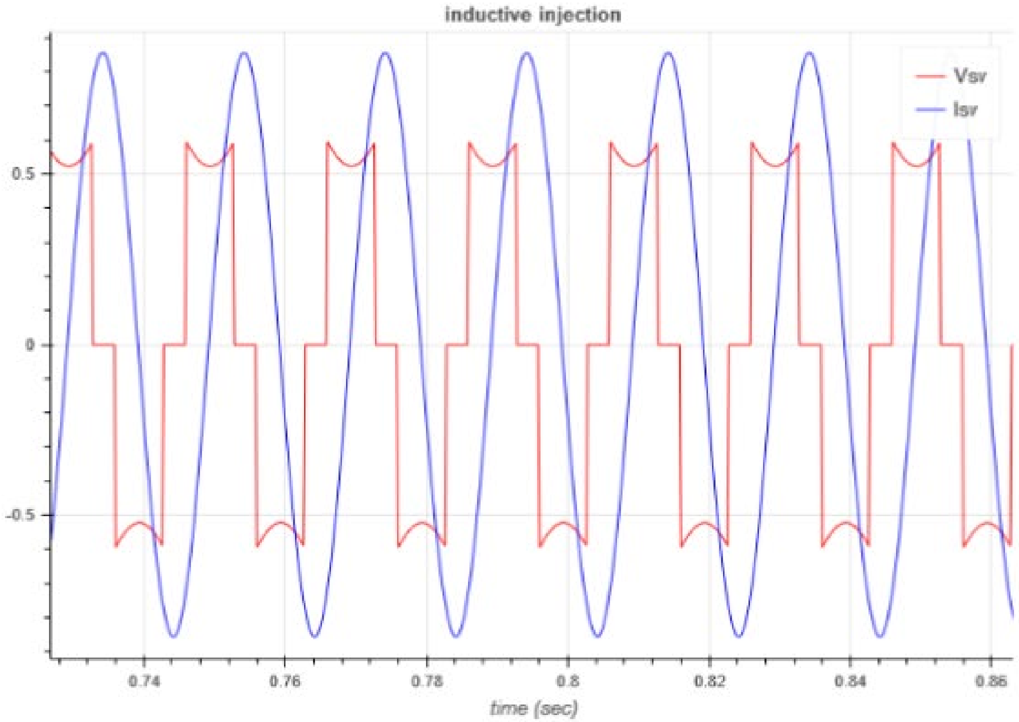
Capacitive Compensation

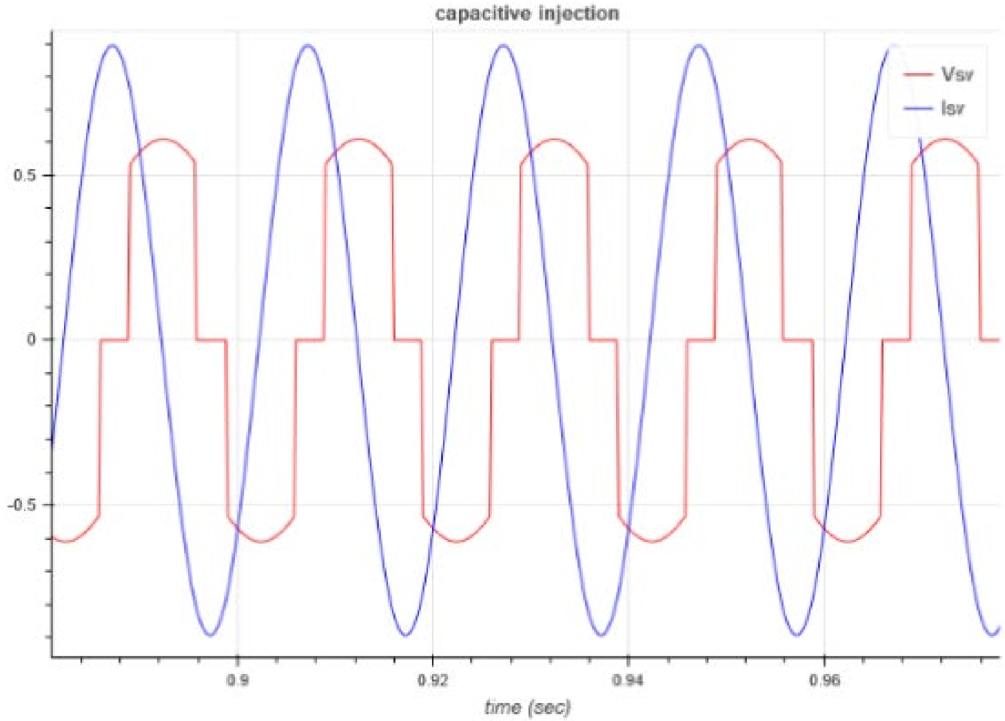


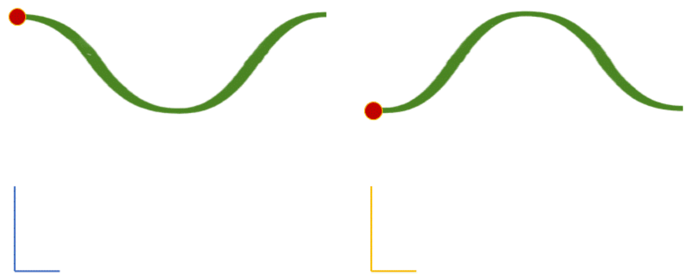
Inductive Compensation

$$\boldsymbol{P} = \frac{|\boldsymbol{V_s}||\boldsymbol{V_R}|\sin(\varphi_s - \varphi_r)}{\boldsymbol{X_1}}$$

Injected voltage - Waveform

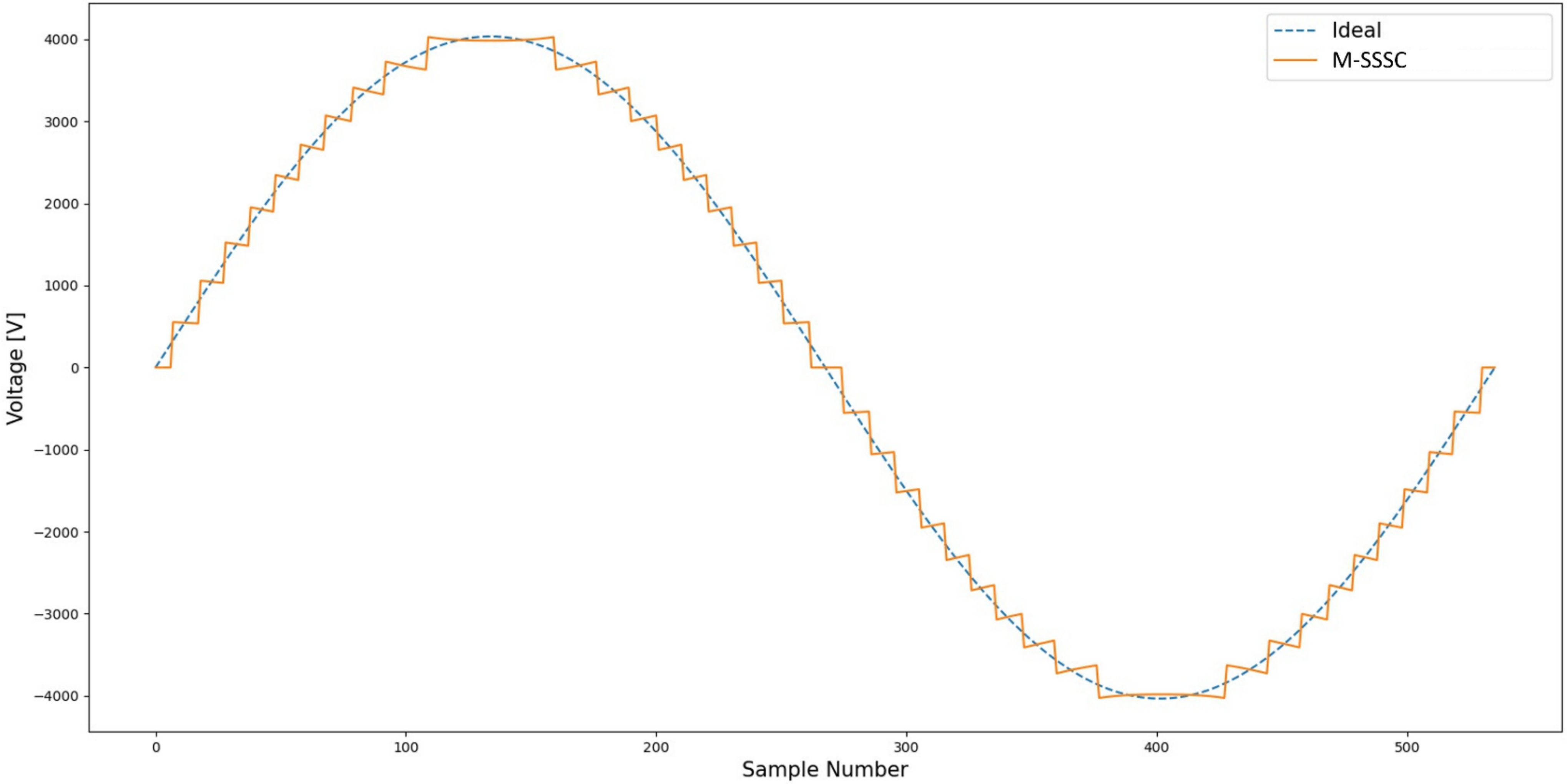






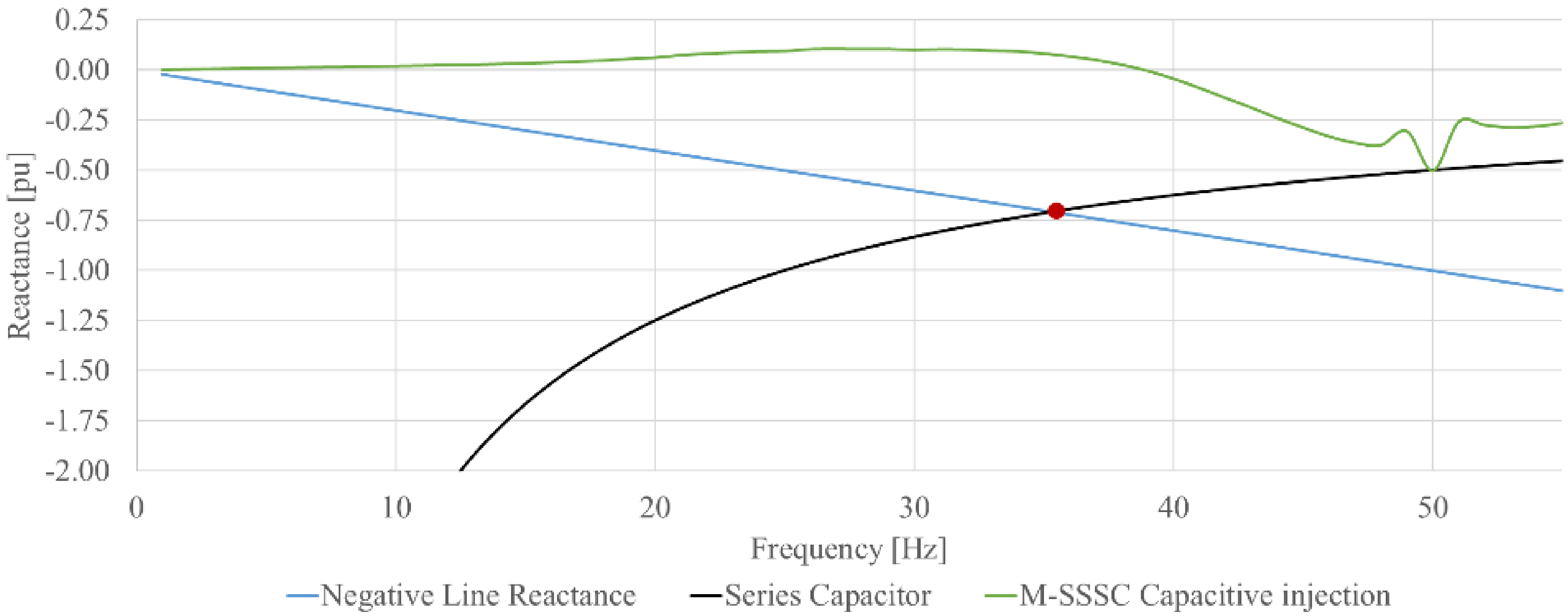
$$Vdc = Vo + \frac{\sqrt{2} I_{RMS}}{wc} (\sin wt)$$

Injected voltage - Waveform



- **Inductive or capacitive**
- **Number of converters**
- **Line Current Magnitude**
- **User's Setpoint**

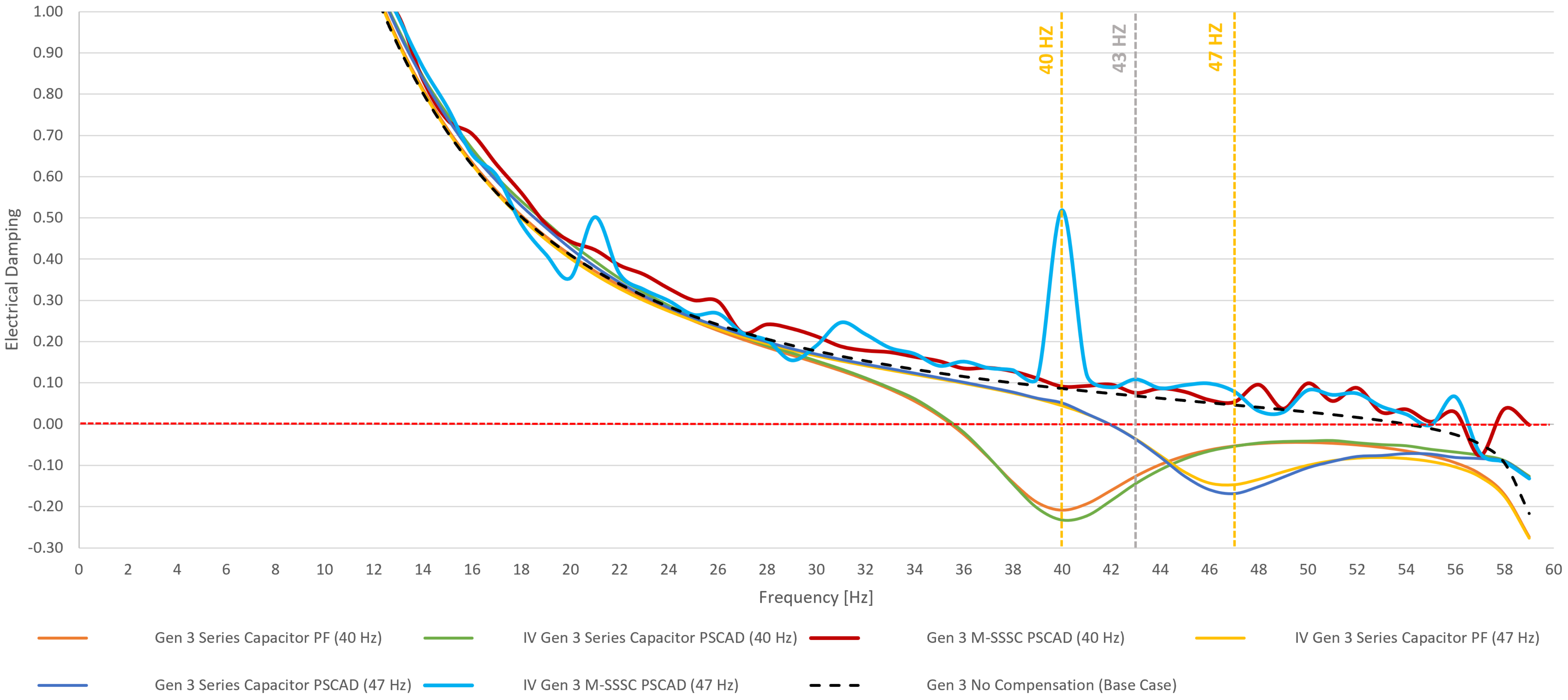
SmartValve Reactance Characteristic



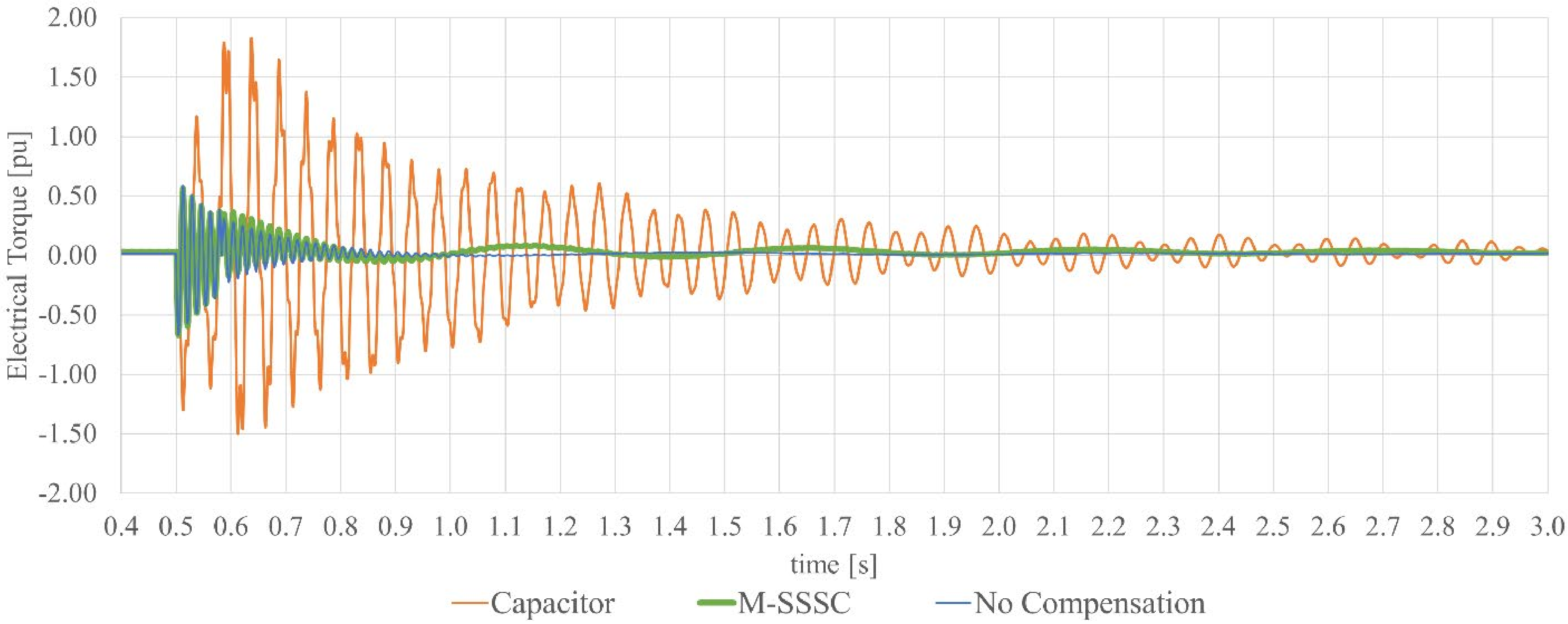
M-SSSC does not follow the traditional capacitor reactance curve

Reactance remains below the natural inductive reactance of the line for all sub-synchronous range

SmartValve SSO Performance Real Deployment



SmartValve SSO Performance First Benchmark System



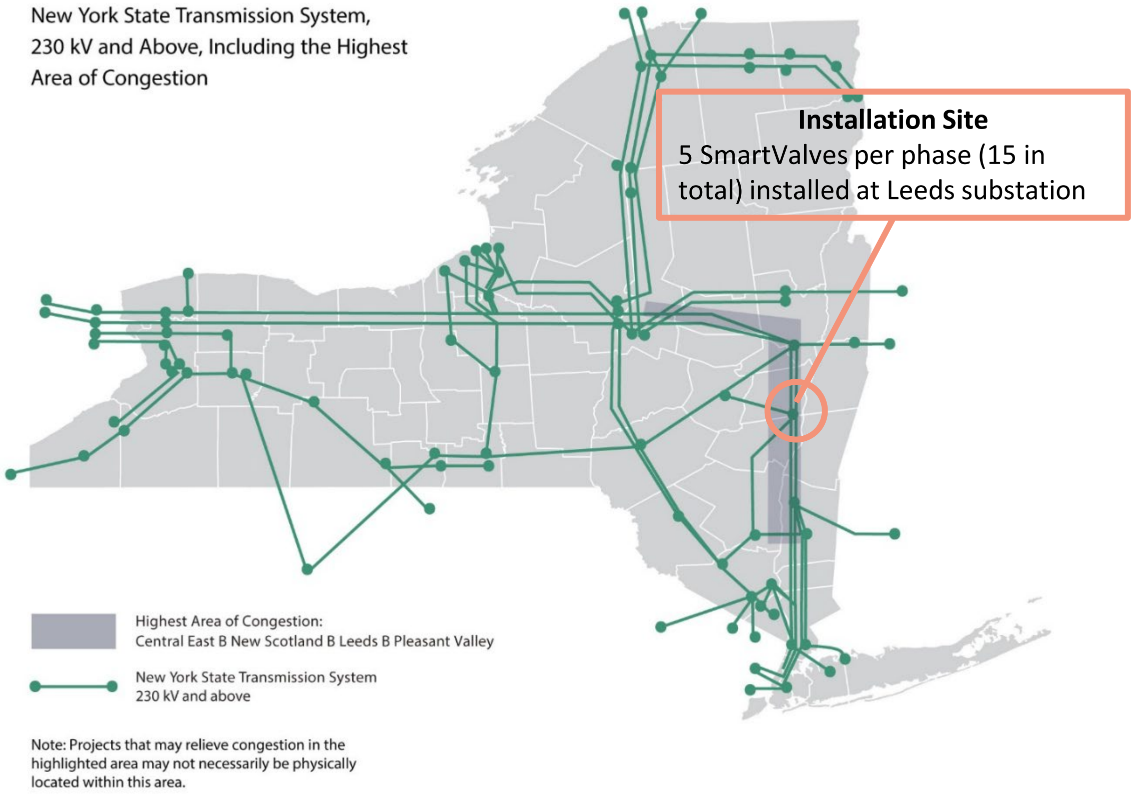
Series capacitor causes 4 times the oscillation magnitude and 8 times the attenuation time

M-SSSC presents an almost identical behavior to the case in which no compensation is used

Use Cases and Operation Modes

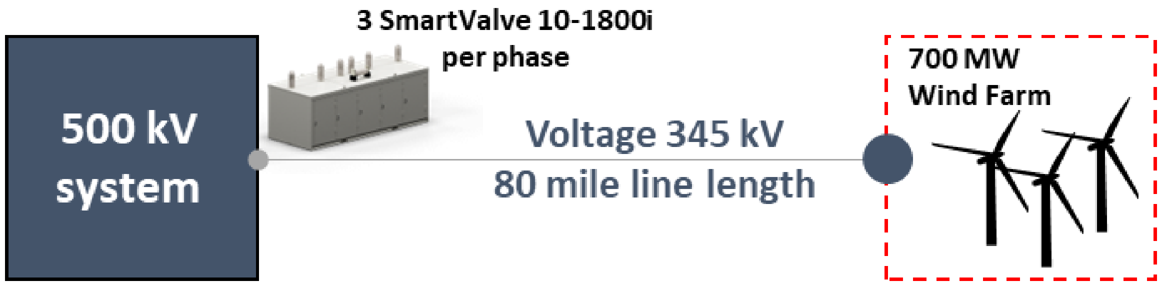
Central Hudson – Leeds – Hurley Ave

- Scoped as a series compensation solution through the NYISO Class Year study process but **concerns with SSR** led them to chose SmartValve
- Unlocks **185 MW** UPNY-SENY while $10M less expensive than the alternative solution
- Deployment design optimized to **use minimal substation space** and scalable over time to adapt to changing system needs.



Optimizing Gen-Tie for Large Wind Farm

- Provides series compensation to maintain voltage stability on high impedance line design, selected to reduce interconnection cost.
- Controllable voltage injection reduces scope, cost, and footprint of required shunt compensation at point of interconnection.
- Additional deployments on surrounding stations can limit impact of proposed RAS, improving overall deliverability from the wind farm
- Estimated $8.5M savings by using optimized line design with SmartValve for series compensation



Optimal Interconnection Design

Double-circuit bundled conductor

- **High cost**
- Low impedance design for stability

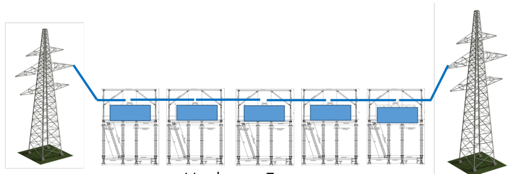
Optimized → Design

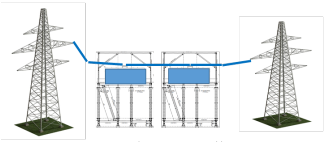
Single-circuit bundled conductor

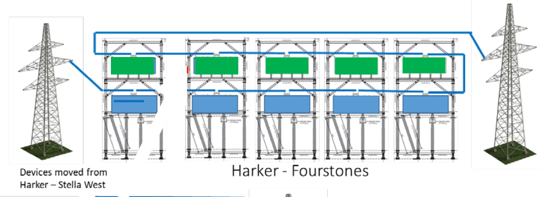
- Cost effective solution
- **Series compensation required for stability**

NGET UK – Harker and Penwortham deployments

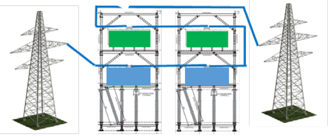
- Circuits in Northern England were increasingly imbalanced, limiting the efficient flow of power especially with increasing generation from northern renewable sources.
- SmartValve technology was deployed across **five circuits at three substations**—Harker, Penwortham, and Saltholme—unlocking **1500 MW** of additional network capacity.
- At Harker and Penwortham, initial deployments in 2020 were further extended by the end of 2023 to enhance impact by **500 MW more**.

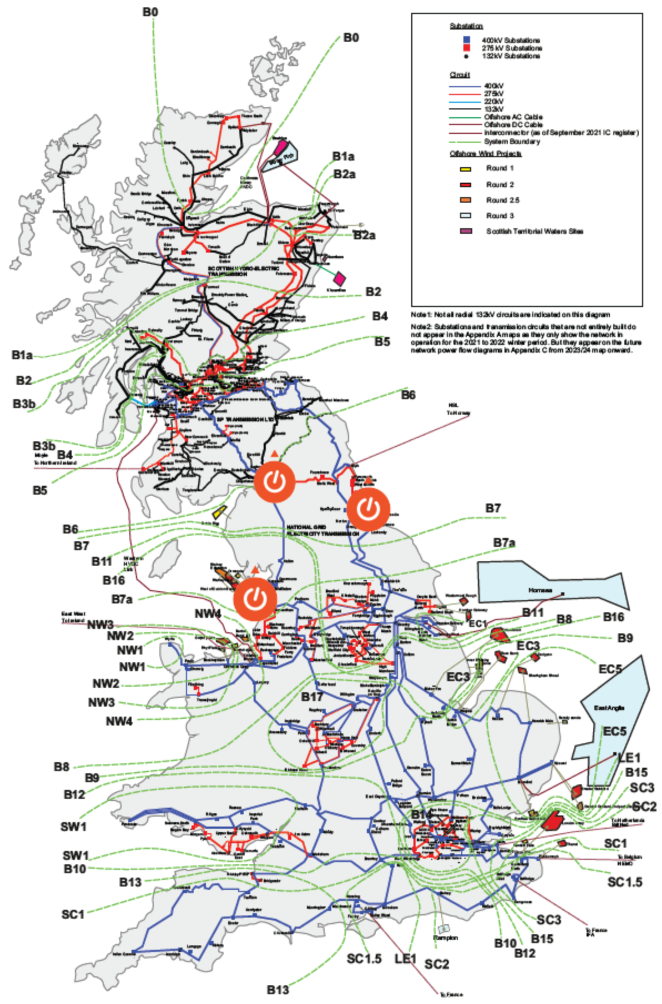

Harker – Fourstones


Harker – Stella West



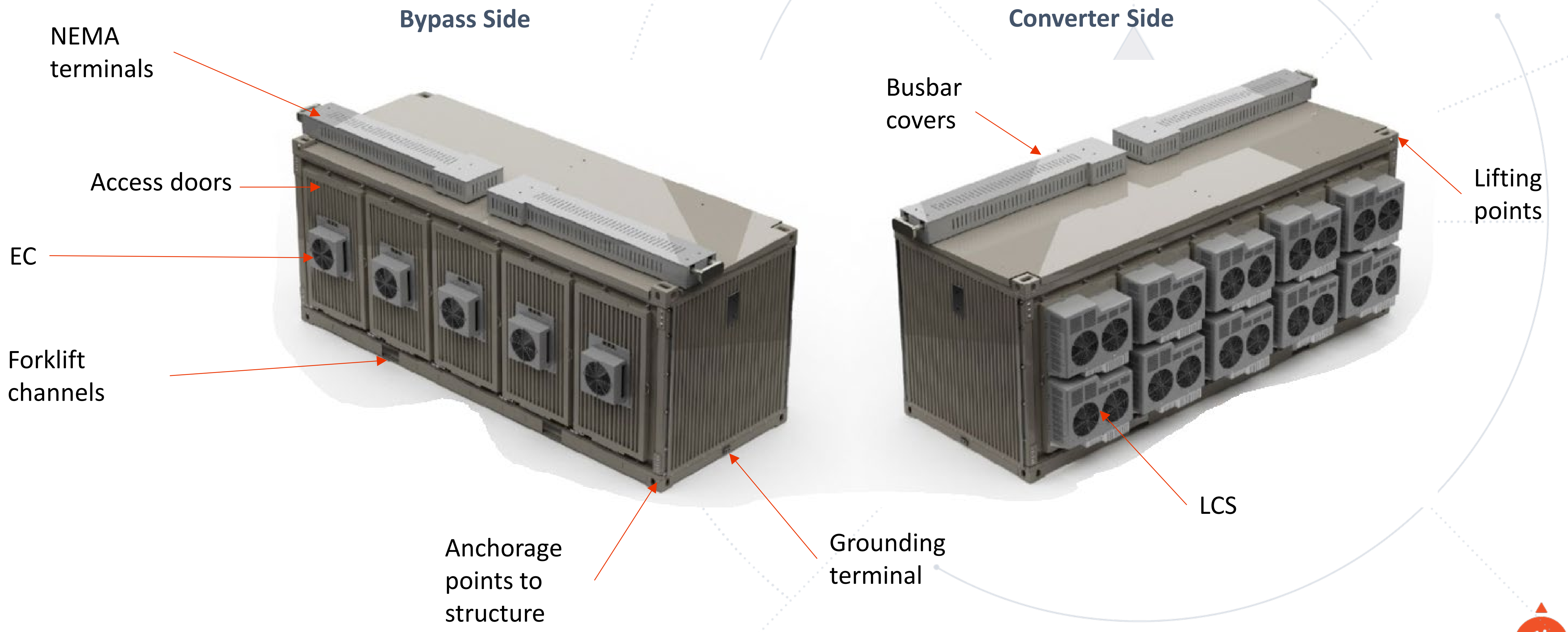
Harker - Fourstones


Harker – Stella West



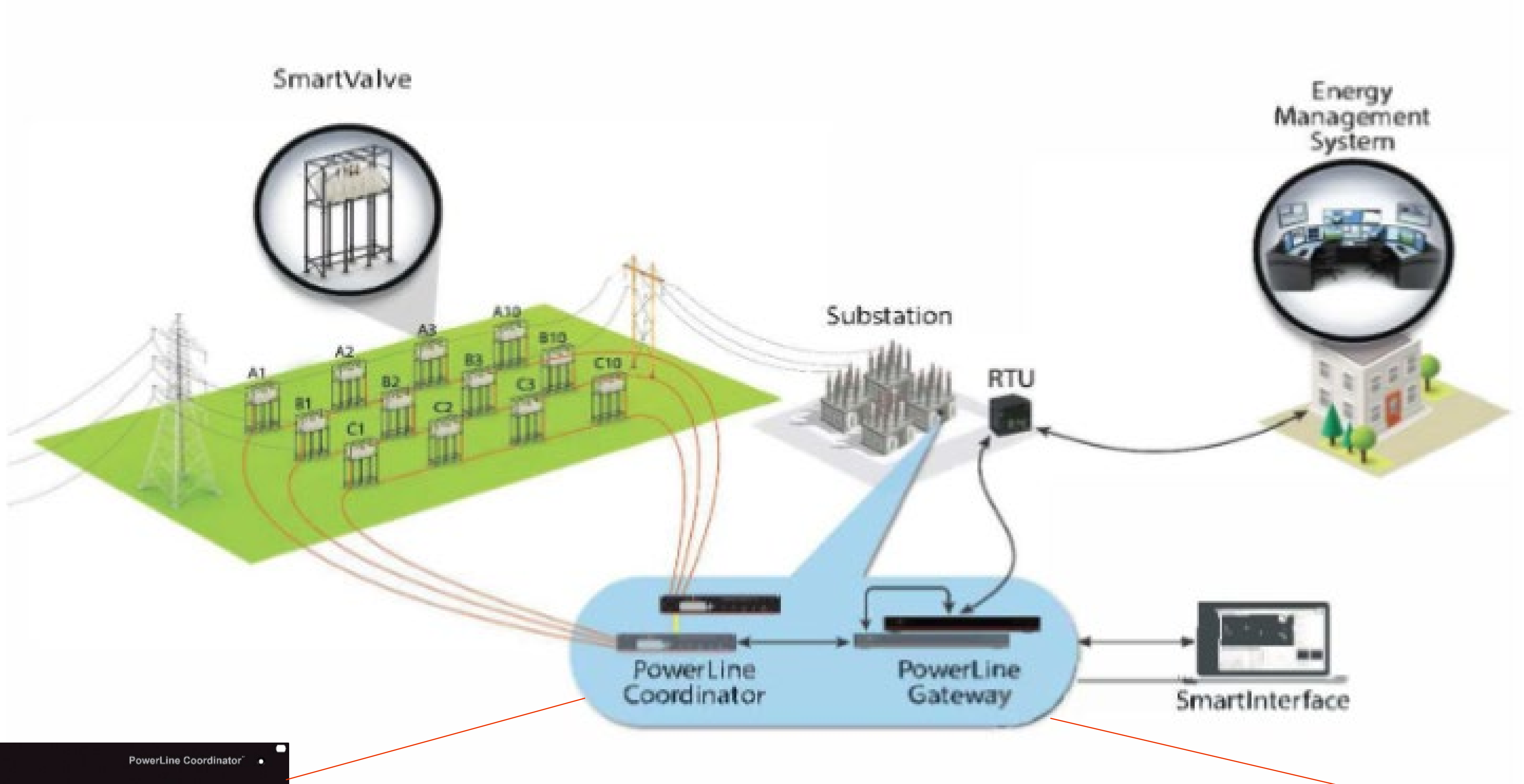
SmartValve 10-1800 v.104

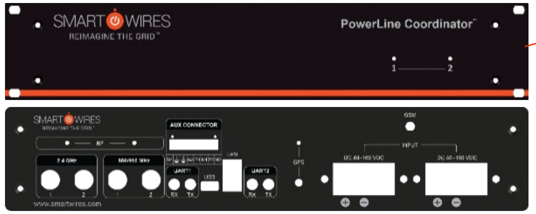
SmartValve 10-1800 v1.04 has been designed to meet the requirements needed in different environments.



 Terms: EC (enclosure cooler) and LCS (liquid-cooling system)

End-to-end Communication and Controls System:





PowerLine Coordinator
(Front and back shown)

PowerLine Gateway
(Front and back shown)

SmartValve control modes

Flexible and adjustable operating regimes

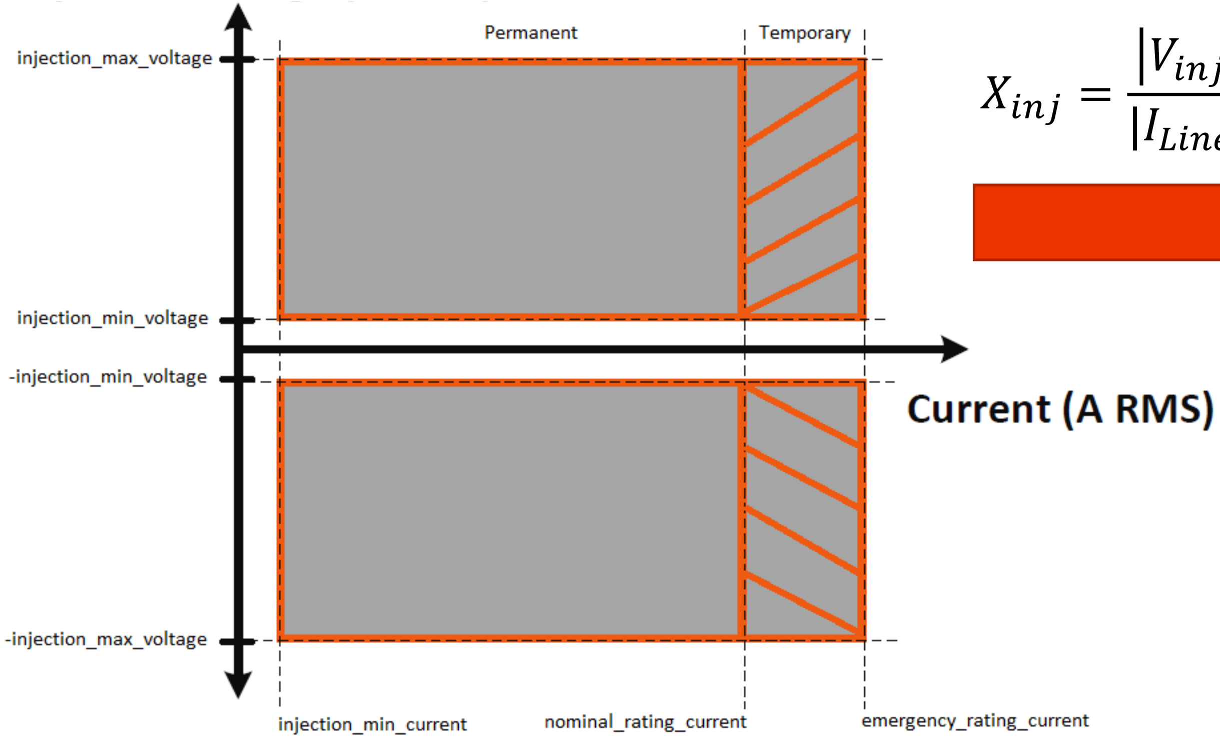
All settings can be changed from the EMS. The number of changes in settings does not affect asset life thanks to the power electronics switching.

	M	**Monitoring Mode**	No voltage is injected as the VSLs are closed or the SCRs are conducting, and the converters are bypassed. Telemetry is sent to the control room through the End-to-End communication system.
Injection Mode	Ω	**Reactance Mode**	SmartValve fleet is configured to generate a fixed reactance that is either capacitive or inductive. The injected voltage will vary as the line current changes to maintain the reactance at a set value.
Injection Mode	V	**Voltage Mode**	SmartValve fleet is configured to generate a fixed voltage injection that is either capacitive or inductive. In this control method, the injected reactance will vary as the line current changes.
Injection Mode	I	**Current Control**	SmartValve fleet actively regulates the magnitude of the current through the facility to stay below a given level.

Terms: EMS (energy management system), SCR (silicon-controlled rectifier), and VSL (vacuum switch link)

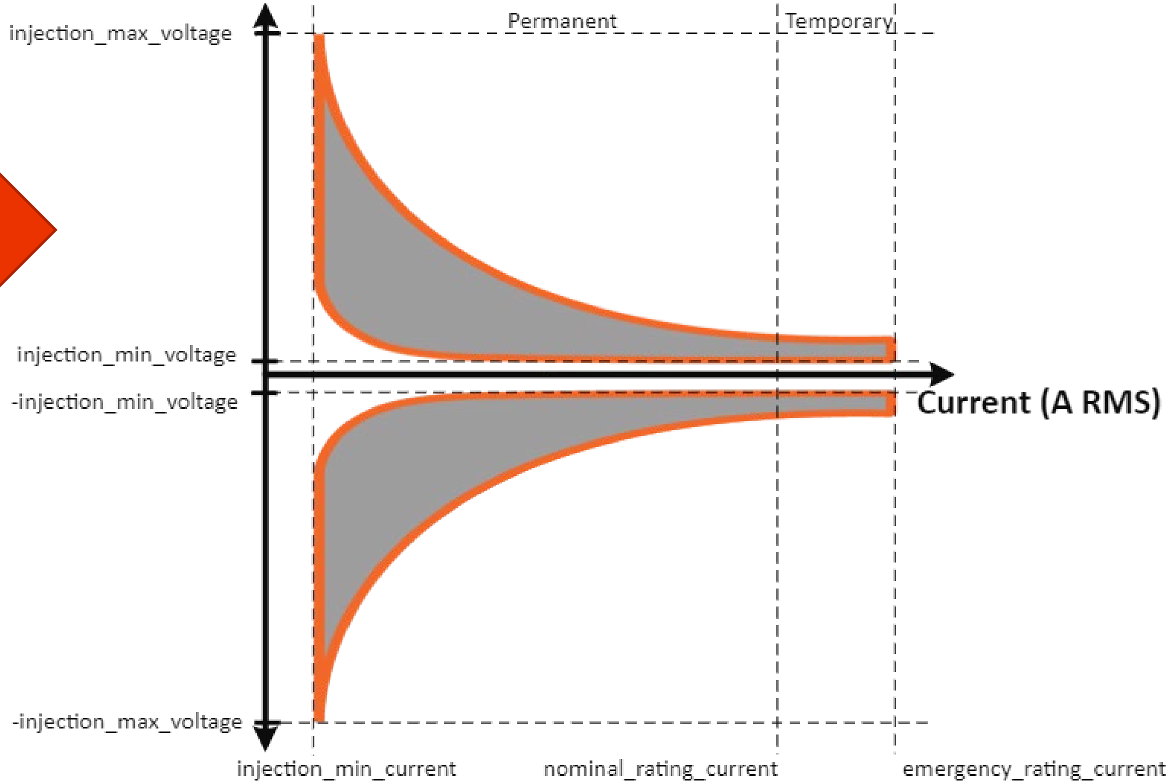
SmartValve Operation Range

Injected Voltage (V RMS)



$$X_{inj} = \frac{|V_{inj}|}{|I_{Line}|}$$

Injected Reactance (Ω)



PG&E – Los Esteros

- CAISO projected a 700 MW load increase in San Jose due to data center growth. A new transmission line is planned for 2032
- After evaluating available options, including reconductoring and energy storage—both of which proved too costly and slow—CAISO identified APFC as the best solution.
- SmartValve will deliver **100MW+** of firm power delivery and is scheduled to be in service at the existing substation within 12 months from PO.

Project contracted in Q4 2024 and will be commissioned in Q4 2025

Southern – Eatonton

- Georgia Power's transmission planning team identified N-1 thermal overloads on two 230 kV circuits, primarily driven by new manufacturing facilities

- SmartValve technology was implemented with specific impedance values (16 Ω for Eatonton Primary-Oasis and 11 Ω for Branch-Oasis), successfully reducing the overloads to acceptable operating parameters.

- New transmission line should be in-service in summer of 2028 which will change flows.