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# Transmission Planning with SmartValve Technology

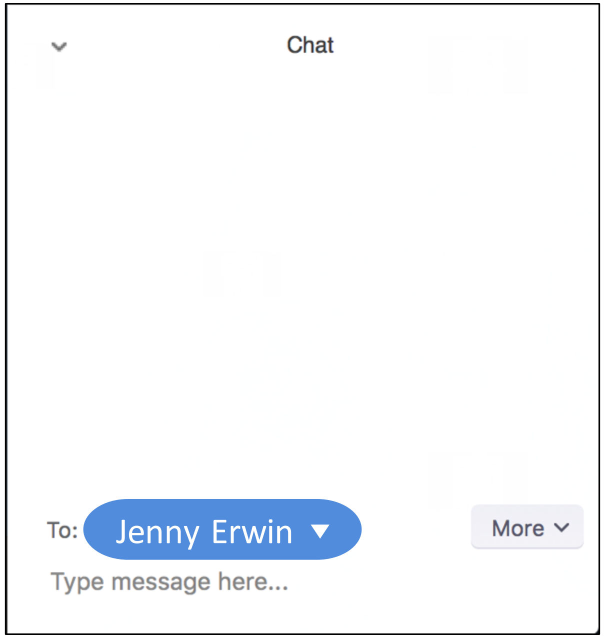
## Modeling and Simulation in PSS/E

**27th March 2020**

# Announcements

## QUESTIONS

zoom




## NEXT WEBINAR

*Reflecting the value of modular, redeployable solutions in a standard planning cost benefit analysis*

**Friday, April 17**
4 PM GMT
(8 AM PT)

**Mark Norton**
VP, European
Business Development
Mark.norton@smartwires.com

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# Today's Presenters

**Brendan Kelly**
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**Alejandro Duque**
Power System Engineer
Alejandro.Duque@smartwires.com

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# Agenda

1. High Level Overview of Technology
2. Typical Planning Use Cases
3. Modelling Philosophy
4. Walk Through of Modeling devices live in PSSe
5. Best Practices and Q&A

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# Smart Wires is the global leader in modular power flow control solutions

- Modular series connected FACTS based Power Flow Controller
- Rapidly deployable and re-deployable
- Flexible, scalable and can be deployed as part of mobile unit
- Minimizing Capital & Risk

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# A potentially challenging time for the Energy Industry post COVID-19 crisis

**Save on Capital Infrastructure Projects**
or defer capital infrastructure projects

**Uncertain Demand – now and into future**
Predicting future load difficult, low oil price, drivers for projects no longer there, etc

**Challenging Build Environment**
Outage Cancellations/Constraints, projects delayed or cancelled

**GHG Reduction Still Required**
Fast track greening of new Generation and Demand Capacity

**Keep and Attract new Industrial Customers** with lower cost grid access

**Maintaining Reliability at lowest Cost**

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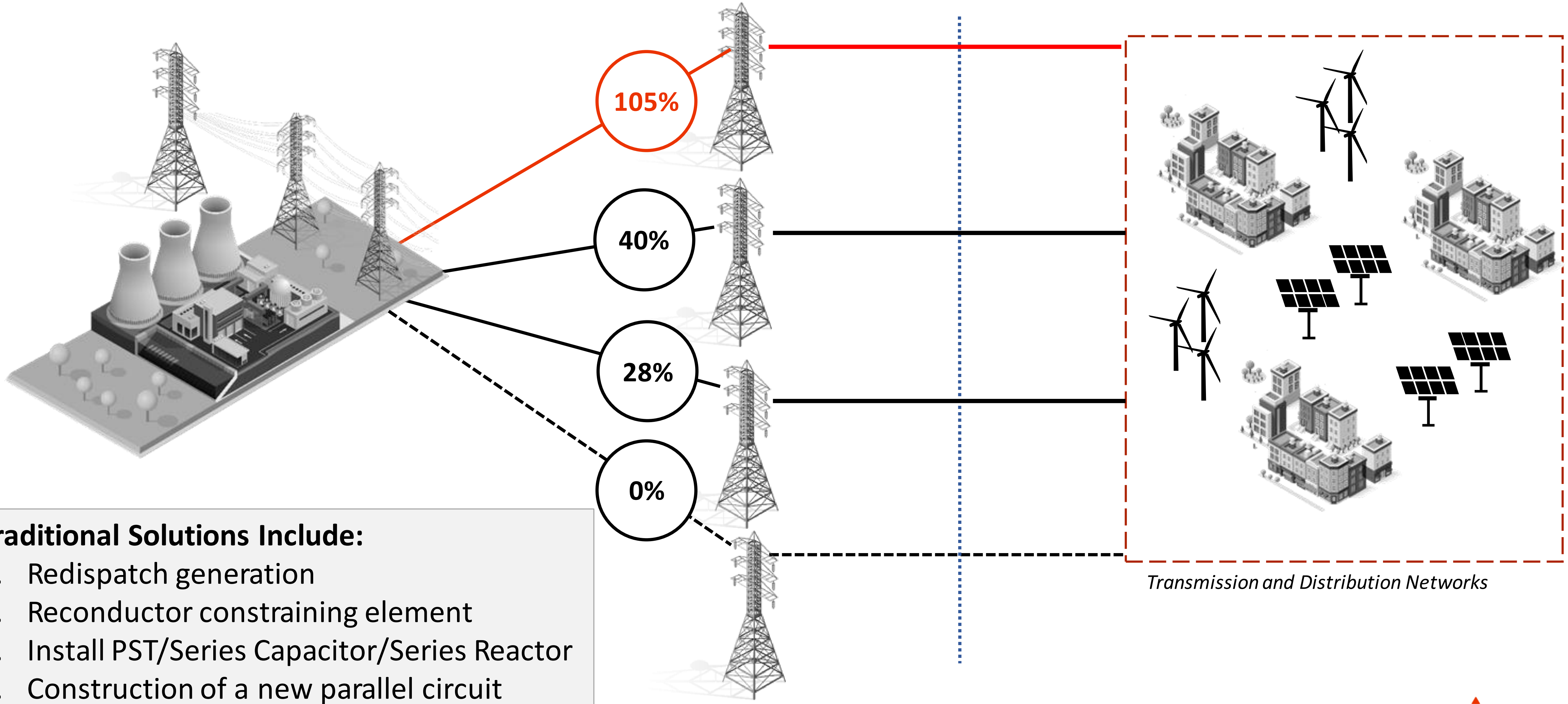
# Before Smart Wires

## Simplified planning scenario predicts network constraint

**Boundary B**

- Sum of thermal capacity after fault = 3000MW
- Max usable capacity due to unequal load sharing = 1600MW
- Max network utilisation = 53%




**Traditional Solutions Include:**

1. Redispatch generation
2. Reconductor constraining element
3. Install PST/Series Capacitor/Series Reactor
4. Construction of a new parallel circuit

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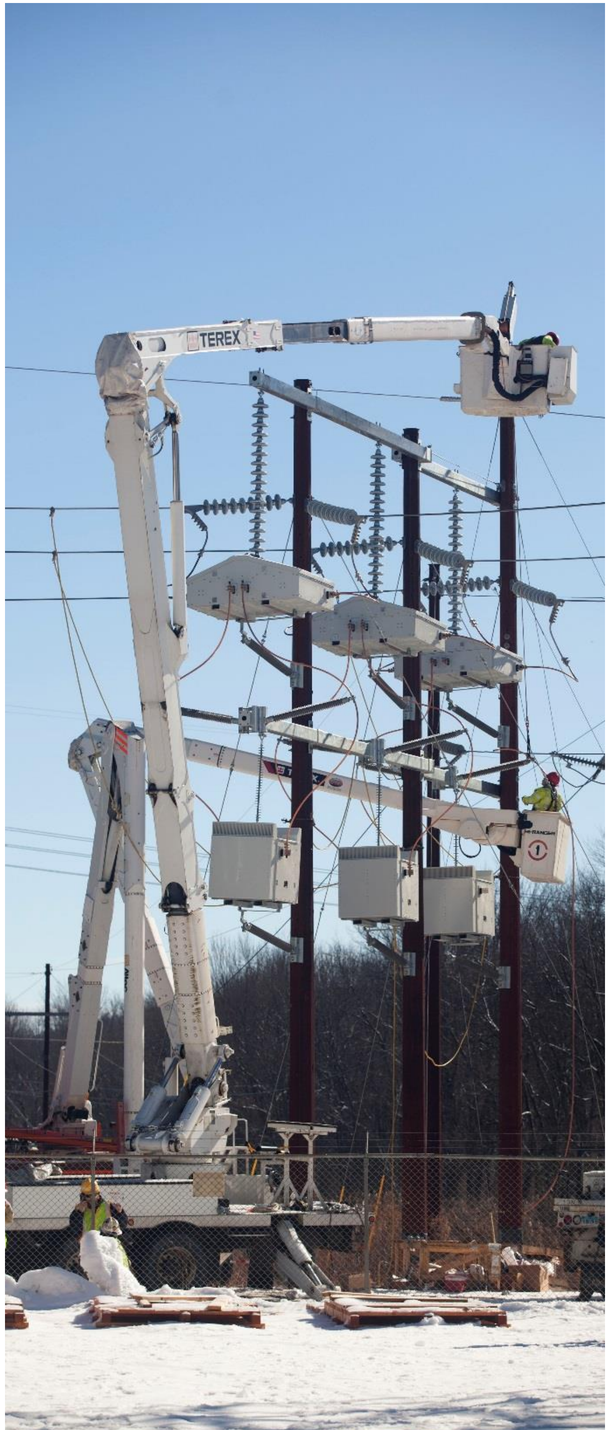
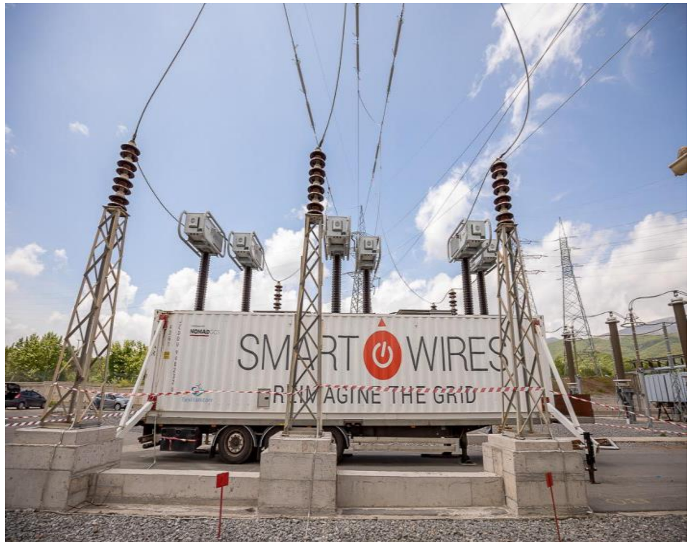
# SmartValve™

Push & Pull Power Flow Control Capabilities

Flexible Deployment Options



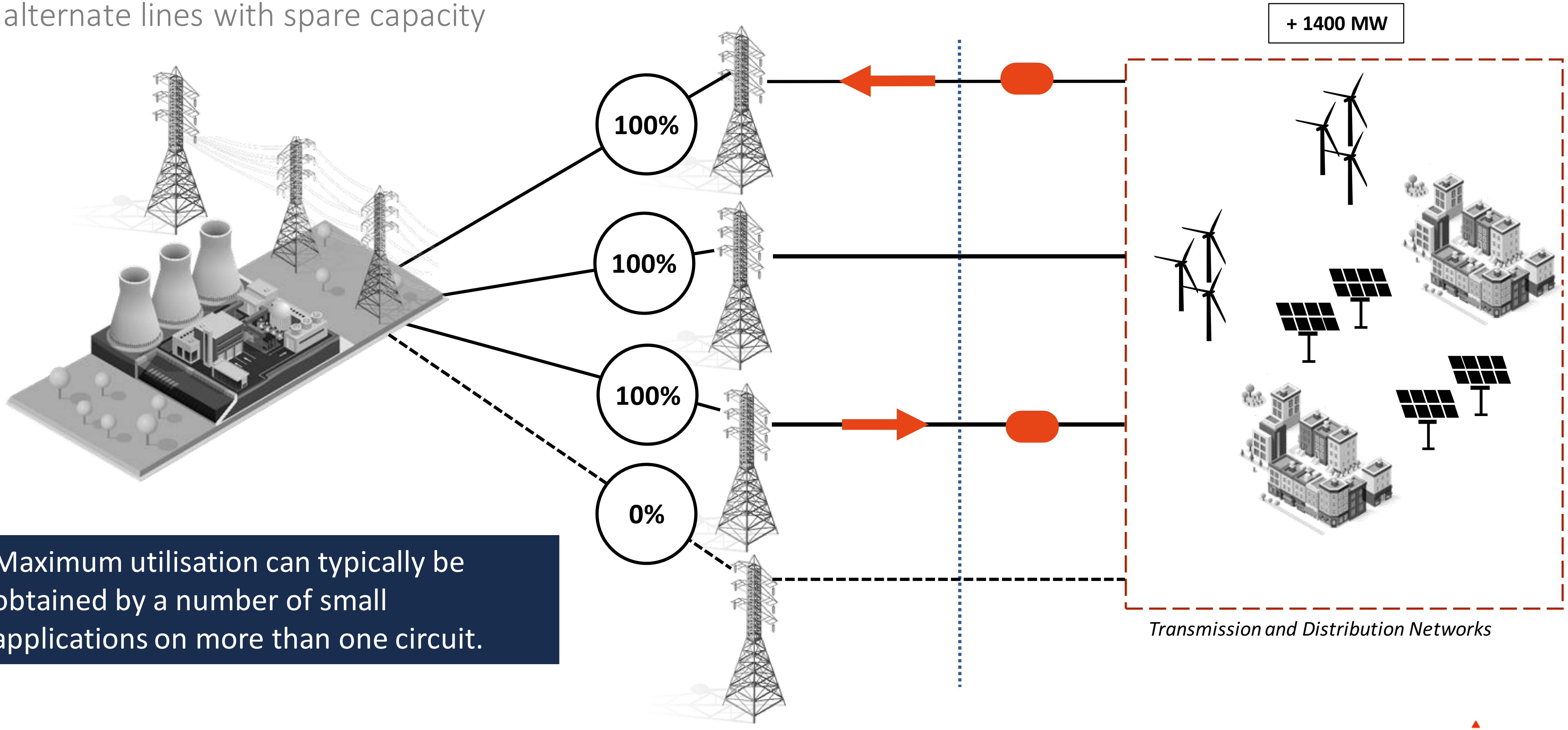




# With Smart Wires Solutions

Power can be PUSHED & PULLED to alternate lines with spare capacity

**Boundary B**

- Sum of thermal capacity after fault = 3000MW
- Max usable capacity due to unequal load sharing = **3000MW**
- Max network utilisation = 100%




Maximum utilisation can typically be obtained by a number of small applications on more than one circuit.





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# Leveraging a Modular Solution as a unique Planning Solution

**Year 1** — **Planning Horizon** — **Year 5**

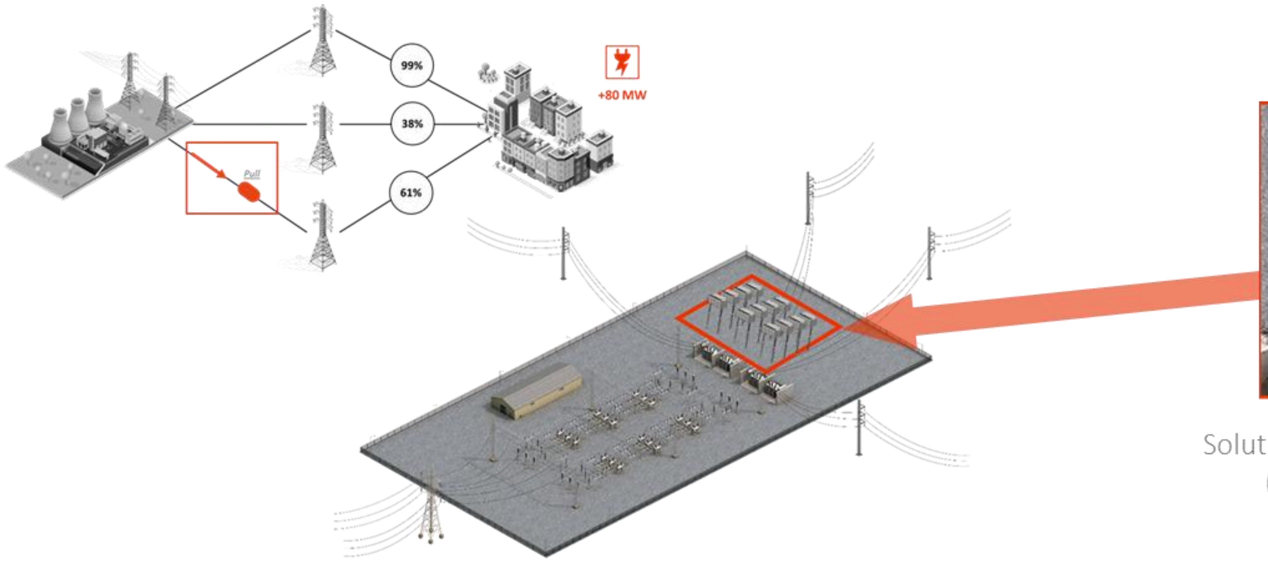
1. **Scalable**
   Scale up or down solution as need arises.

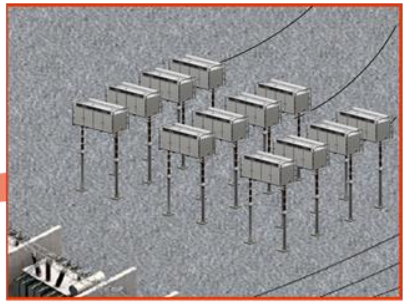
2. **Faster Delivery**
   Contract to Delivery in less than 1 year. Meet emergent needs quickly.

3. **Movable**
   Ability to move or redeploy if need changes.

4. **Minimize Risk**
   Scale up solution to meet needs of today, minimizing long term investment risk.

5. **Flexibility**
   Greater flexibility in how solutions are deployed to meet all network needs.



Solution can be easily and quickly expanded (or contracted) to adjust topology

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# Enabling the Energy Transition

## A collection of projects completed or underway globally

**+1.5 GW**

Solution provides capacity within 18 months and can easily scale to provide more than 4 GW of increased transfers.

**+ 170 – 220 MW**

Dialing line reactance in real-time based on how hard the wind is blowing at various locations ensures optimal transfers are possible regardless of operating conditions

**+ 190 MW**

Tunable voltage injection avoids risk of SSR and associated operational issues while yielding a 70% footprint reduction compared to traditional series compensation.

**+ 95 MW**

Power flow control saves over $10 M versus reconductor alternative and avoided reinforcement works in urban environment.





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# We can help solve these types of problems with SmartValve

| | |
|---|---|
| **Increase Network Transfer Capacity** | SmartValve is a low cost alternative to Series Compensation, Phase Shifting Transformers, Re-conductors and New Line build network options which increase network transfer capacity. |
| **Bridge Solution** | Where longer term network reinforcements are needed, SmartValve can provide interim or bridge solution to resolve network needs while the longer term solution is put in place. |
| **Interconnect Load Customers** | Rapid deployment nature of SmartValve can release network capacity for new load types that can quickly ramp up their demand such as Data Centres and Vegetable Grow House loads. |
| **Renewable Interconnections** | Work with Utilities or Renewable Developers to identify low cost, quick connection options to traditional network solutions. Smart Wires' solutions can also alleviate short or term network congestion. |
| **Facilitate Network Outages** | Using the SmartValve Mobile solution can help enable challenging and critical construction/maintenance projects to be completed and redeployed after the outage has been completed. |
| **Emergent/Near Term Needs** | Delays in completing projects, new generation or demand connections, changing demand causing changing network flows can sometimes result in emergent needs on the network that SmartValve can help manage. |

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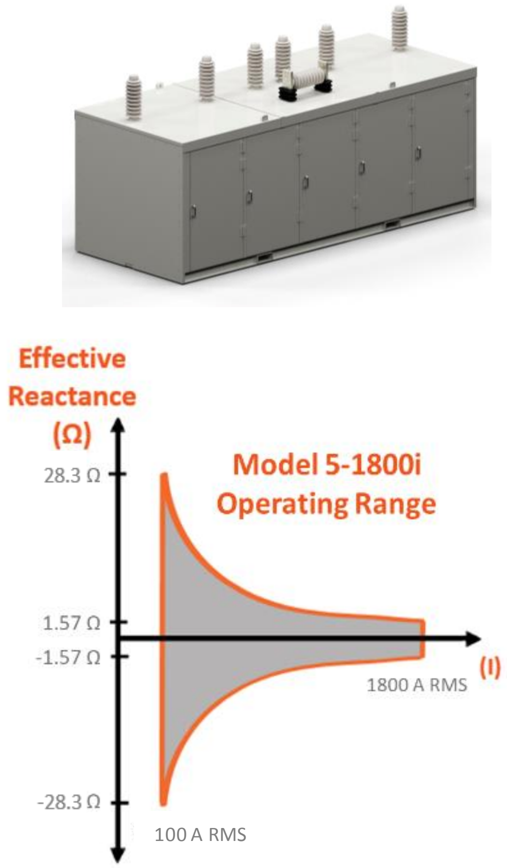
# Technical Overview

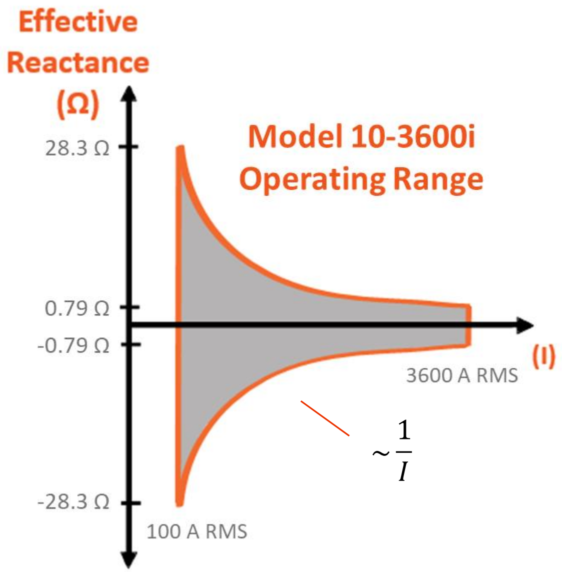
# SmartValve™ Overview

**The first intelligent, bi-directional "valve" for the electric grid**




- The **SmartValve** injects a voltage in quadrature with the line current such that it is capacitive (- Ωs) or inductive (+ Ωs). However, unlike physical capacitors or inductors, the injected voltage is independent of the line current.
- The curve shows the range of injected reactance as a function of the line current. The outer orange boundary is when the **SmartValve** is injecting the full output voltage, in this case ± 2830 V RMS.

# SmartValve™ Overview




- **Operational limits of deployment depend on type and number of devices**
- Operational limits expressed in Volts (maximum Voltage Injection)
- Maximum equivalent reactance injected depends on line current and voltage limits

For a given injected voltage, maximum equivalent reactance equals:

$$X_{effective}^{max} = \frac{V_{injected}}{I_{min\ line}}$$

For a given line current, maximum equivalent reactance equals:

$$X_{effective} = \frac{V_{injected}^{max}}{I_{line}}$$

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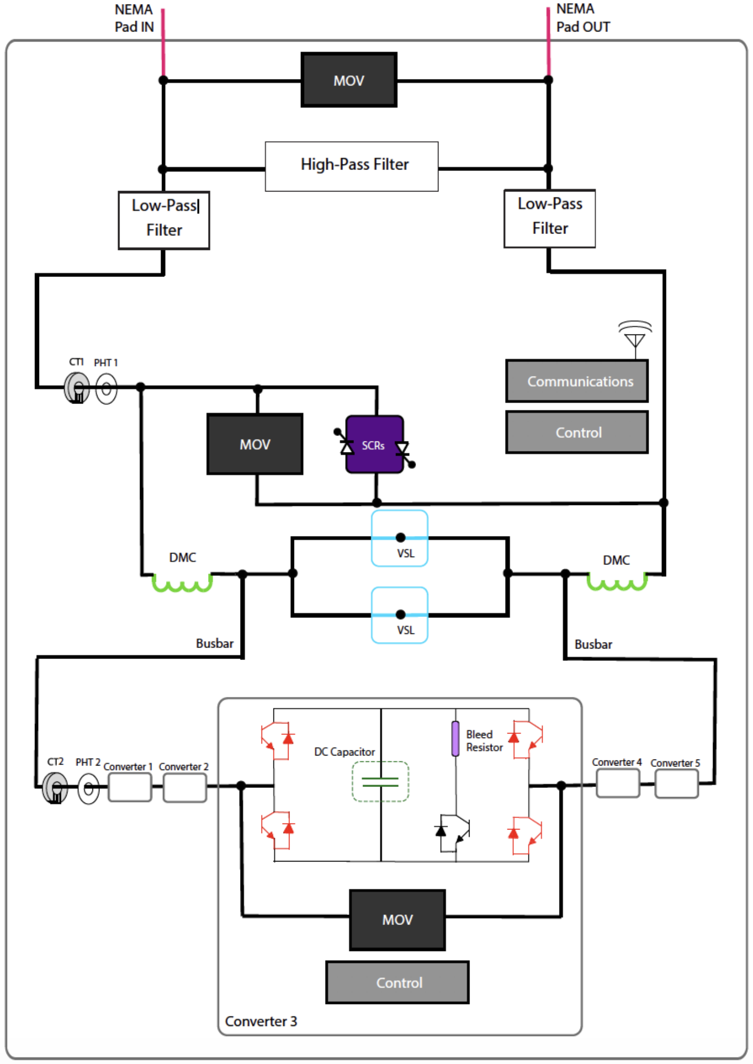
# System Overview

SmartValve




Filter

Bypass functionality

Injection functionality





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# SmartValve Control Modes

## Flexible and tuneable operational regimes

Ω

**Reactance Mode**

The SmartValve fleet is set to output a fixed reactance that is either capacitive or inductive. In this control method, the injected voltage will vary as the line current changes to keep the reactance at a set value.

V

**Voltage Mode**

The SmartValve fleet is set to output a fixed voltage injection that is either capacitive or inductive. In this control method, the injected reactance will vary as the line current changes.

I

**Current Control**

In this control method the SmartValve fleet actively regulates the magnitude of the current through the facility to stay above or below a given level.

**Set Point**

In this control method the SmartValve fleet is set to control a parameter to a preset amount. This amount can be a pre-set reactance, injected voltage, or operating current level, making it easy to switch directly to a known operating state.

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# Modeling Approach



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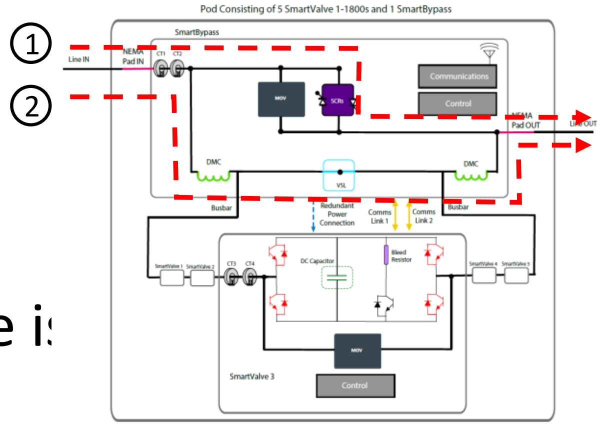
# Steady-State Approach

## 2-State-Model (On/Off)

### Bypass Mode

- Current flows through the SmartBypass
    1. During fault mode; or
    2. During monitoring mode
- In either case, the injected voltage of the SmartValve i

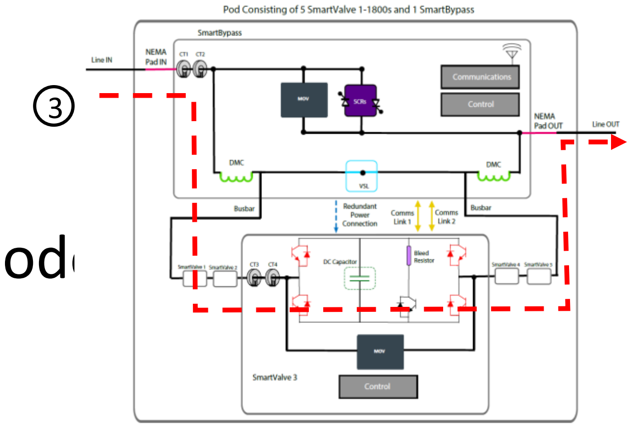
➢ Voltage and impedance across SmartValve approx. 0




### Injection Mode

- Current flows through the SmartValve
    3. During injection mode
- SmartValve injects voltage dependent on control mod
    - Voltage, Current, or Reactance

➢ Manipulation of voltage to meet target set point



# Steady-State Approach

## Software Packages Determine Model Approach

- SmartValve injects voltage with an angle of approx. 90 leading/lagging the line current
  - Some software packages for steady-state simulation have limitations to model voltage sources
  - SmartValve effectively modifies line’s reactance by injecting an ideal voltage
- SmartValve modeled as dynamic line component dependent on mode and set point

**Monitoring Mode**

$V_{injected} = 0$

$X_{effective} = 0$

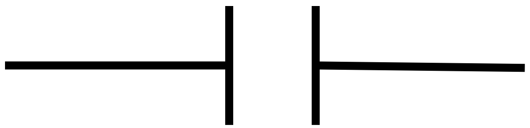
**Inductive Injection**

$V^{+}_{injected} > 0$

$X_{inductive}$

**Capacitive Injection**

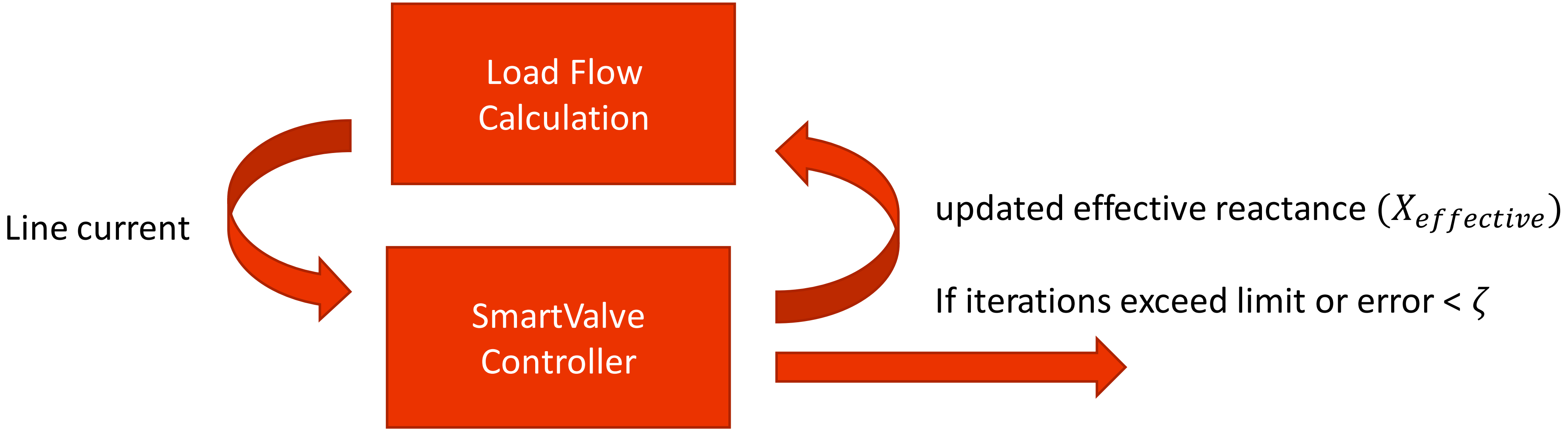
$V^{-}_{injected} < 0$



$X_{capacitive}$

# Steady-State Approach

## SmartValve Controller in Injection Mode




- Steady State models are all reactance based using the following relation:

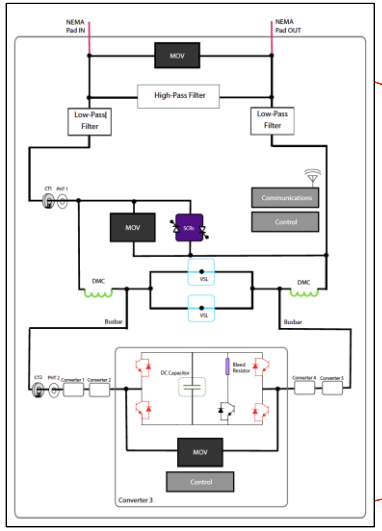
$$X_{effective} = \frac{V_{injected}}{I_{line}}$$

- Updated effective reactance leads to a change of line current in load flow calculation

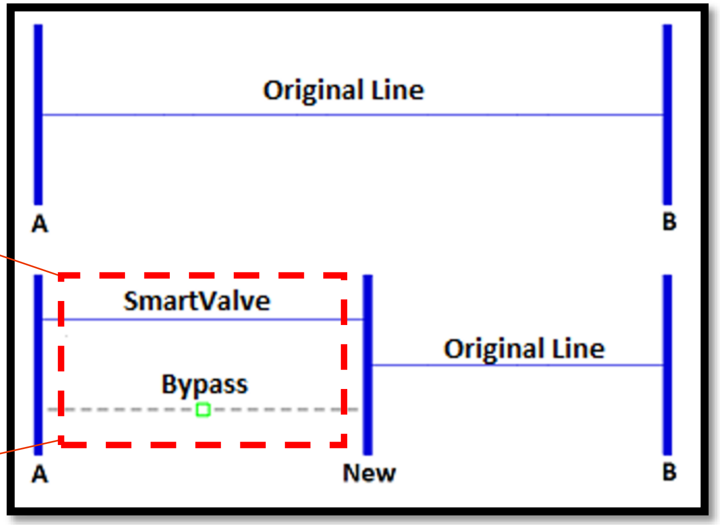
➢ Iterative procedure updating the effective reactance

# Hands On
# PSS/E Steady State Model

# PSS/E Steady-State Model



External library of SmartValve Controller




- SmartValve deployment is modeled as two components:
  - SmartBypass: low-impedance branch (almost equal to 0 Ohms)
  - SmartValve: dedicated branch with reactance dependent on SmartValve injection.

- SmartValve deployment and operations parameters are stored in separate files
- SmartValve Control Modes: Current, Voltage, Reactance, Full-pull and Full-push mode



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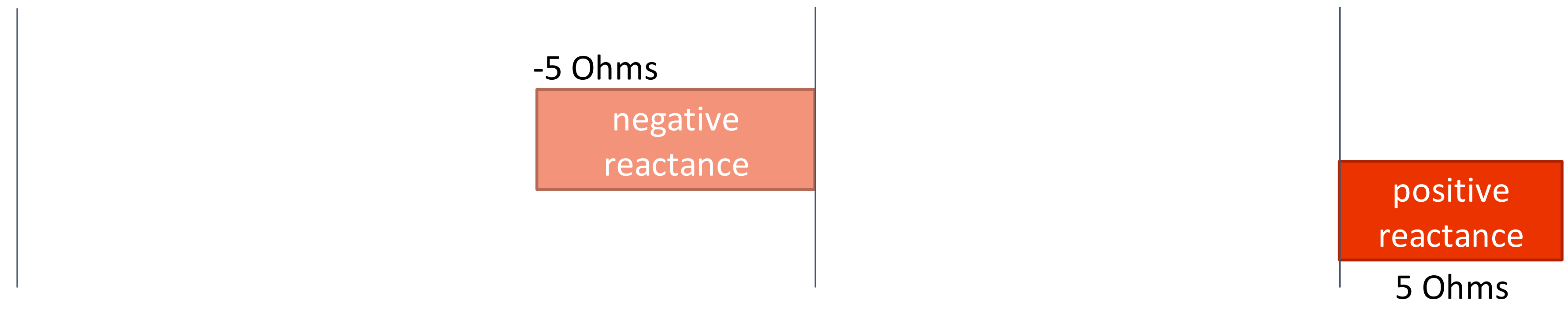
# PSS/E Steady-State Model

**Bypass Mode (off)**

**Total ≈ 0 Ohms**

**Injection Mode (on)**

**Total = -5 Ohms** | **Total = 5 Ohms**




**Monitoring Mode (Bypass short-circuit SmartValve):**

- Total $X_{effective}$ almost equal to 0 Ohms (low impedance branch)

**Injection Mode:**

- Maximum effective reactance injected depends on line current and voltage injection capability
  - Minimum $X_{effective}^{-}$ (capacitive) equal to $\frac{V_{max\_inj}^{-}}{I_{line}}$
  - Maximum $X_{effective}^{+}$ (inductive) equal to $\frac{V_{max\_inj}^{+}}{I_{line}}$





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# PSS/E Steady-State Model

## Useful information – User Guide

### Driving the Tools with Python

An alternative to using the tools through the PSS/E client is to use the tools via Python itself. This may be convenient for users who are accustomed to the Python language and would be recommended if the user typically drives PSS/E with Python by default. An example script is shown below in Figure 15.

### Sizing and Location Tool

This section of the user guide presents a set of heuristic-based methodologies for planning with SmartValve™ technology using PSS/E v33 or v34 and Python 2.7. The planning methodologies covered in this document involve the identification of thermal overloads in meshed networks and the solution development process taken to efficiently mitigate them with SmartValves.

# Study Best Practices



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# General Tips

1. It is highly recommended to automate and build a reproducible data analysis pipeline for the study being performed.
2. SmartValve can change reactance on command, it should not be modeled as a fixed reactance for all cases and all contingencies. For best results, it is recommended to use Smart Wires' developed models and scripts available for a variety of software packages.
3. Typically the most effective location to deploy SmartValve to resolve an overload is on the overloaded facility itself. However, SmartValve can be deployed on facilities other than the overloaded one and still control the power flow on that specific point. This approach has been used to manage loading on facilities that are not easily deployed (e.g. transformers).
4. Operating the SmartValve in capacitive mode on an unloaded transmission facility may require fewer units to relieve a constraint than operating it in inductive mode given that the SmartValve's maximum reactance is higher at lower currents.
5. If unable to resolve an issue with a SmartValve solution, please inform Smart Wires of the issue. Smart Wires has worked with utilities across the globe and in doing so has co-developed non-intuitive solutions.



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