MITSUBISHI ELECTRIC
Changes for the Better

10th Annual University of Pittsburgh Electric Power Industry Conference

"System Studies for Grid Level Integration of Power Electronic Devices"

Presentation
November 16, 2015
1:30 PM Session

Adam R. Sparacino
System Studies Engineer

Outline of Presentation

- Introduction to Power System Engineering Services Department
- Studies for Power Electronics Installations

Introduction to Power Systems
Engineering Systems Department

Power System Engineering Services Department

- 17 full-time employees
- Three remote offices
  - Albany, NY
  - Galveston, TX
  - Pomona, CA
- Three Specialty Teams
  - Power Electronics Team (New Technology Support)
  - Transients Team (Equipment/Apparatus/Substations Support)
  - Stability Team (Operations/Planning Support)

Scope of Experience

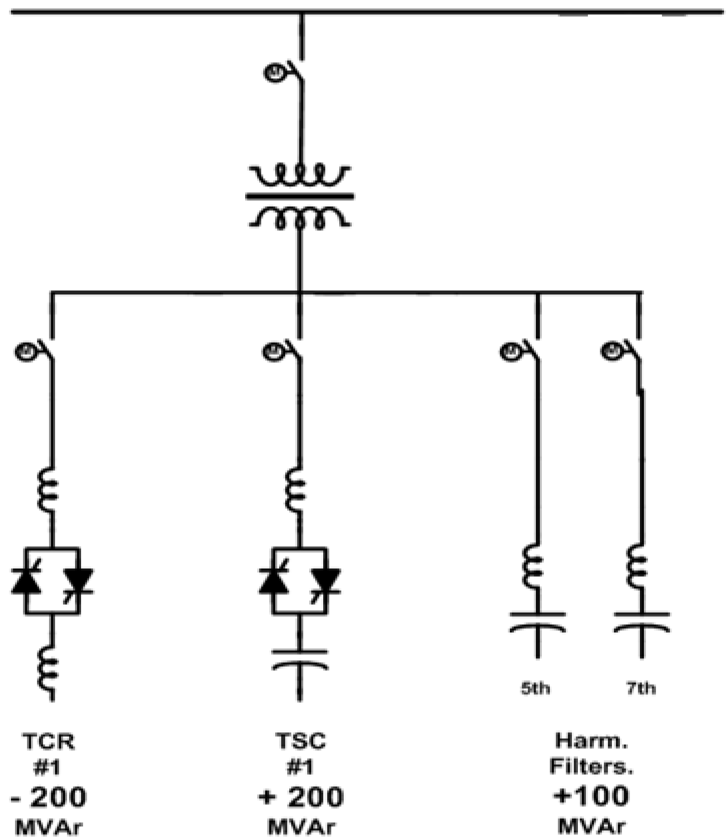
- Nationwide utility and industrial applications
- Voltages ranging from 800kV to 120V (200+mi lines to 0.5ft cable)
- Steady-state to microsecond timeframes
- Software: PSS/E, PSLF, PowerGem TARA, PSCAD, EMTP-RV, MATLAB, CDEGS, ASPEN, Python, E-Tran
- Active participation in industry organizations such as IEEE, CIGRE, WECC, NYISO, SPP, ERCOT, PJM

Reasons for Performing Studies

- Ensure compliance with ANSI/IEEE Standards
- Ensure compliance with regional operating criteria and specific operating procedures, philosophy, and safety/maintenance standards
- Ensure equipment suited for application of interest
- Review/confirmation of results and recommendations
- Balance work-loads
- Re-visit procedures under new system conditions
- Perform discovery-type work on advanced system topics

Key Studies for SVC (Static Var Compensator) Installations

Example One-Line of SVC



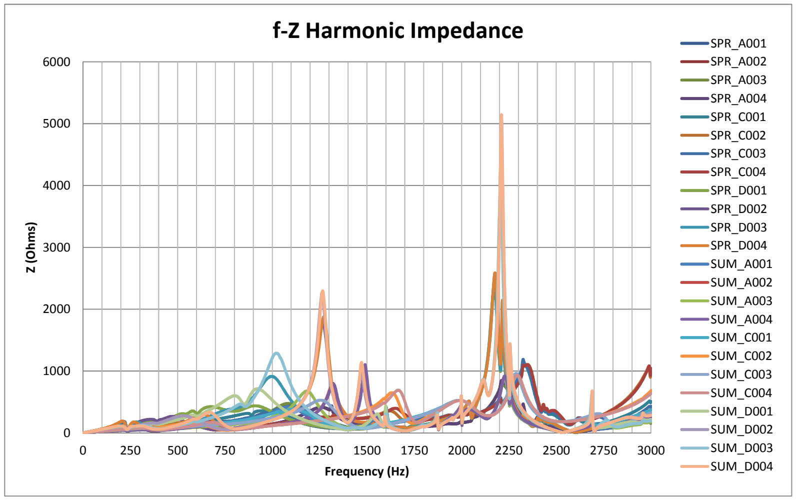
General Studies for Design and Validation of SVC Equipment

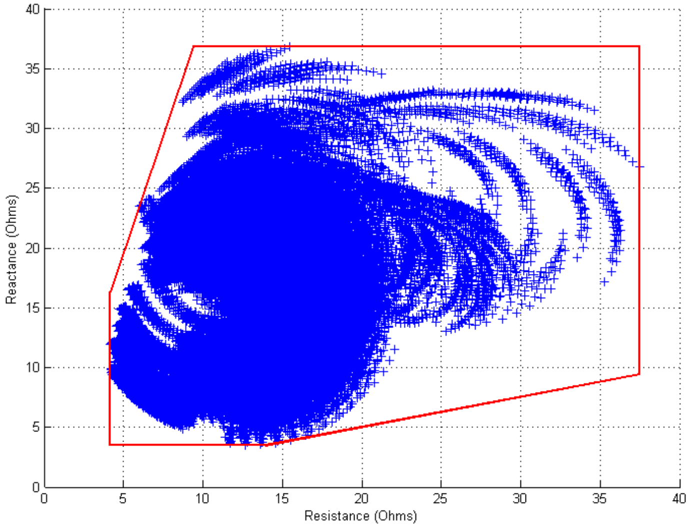
- Harmonic Impedance Analysis
  - Determine range of possible system impedances for use in design and rating of SVC equipment
- Step Test Analysis
  - Determine settings of controller gains such that the SVC operates quickly enough and remains stable for desired range of system strength.
- Electromagnetic transients and insulation coordination analysis
  - Determine the maximum voltage and current stresses for all possible system operating conditions.
- Dynamic Performance Analysis
  - Verify that the SVC operates as intended in response to major system disturbances and that no adverse interaction exists between nearby power system equipment.
- Interaction Studies (special - as needed)

MITSUBISHI ELECTRIC
Changes for the Better

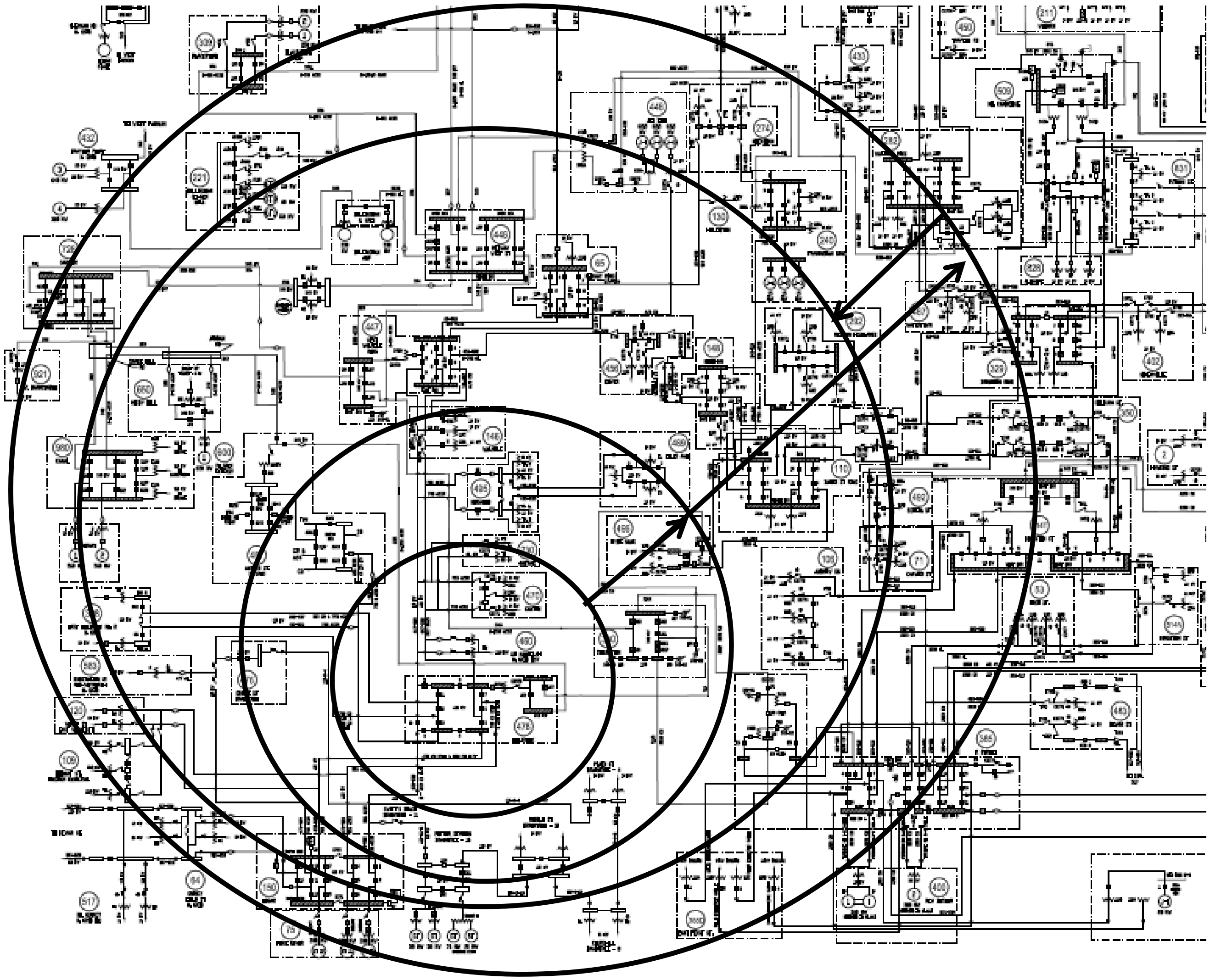
Harmonic Impedance Sectors

- AC filter design for an SVC is influenced by the harmonic impedance of the system.
- Calculate harmonic impedance sectors
  - Examine different loading conditions
  - Examine various operating conditions



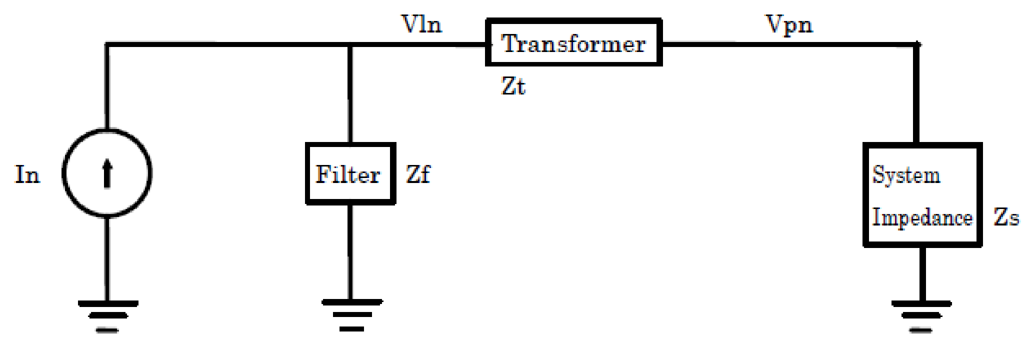


Harmonic Impedances Sectors



Harmonic Performance and Equipment Rating Analysis

- Results from the harmonic impedance analysis are included in the design of the SVC.
  - Verify the harmonic performance of the SVC equipment design
  - Incorporate harmonic impedance sectors, measurement data ,and TCR harmonic currents



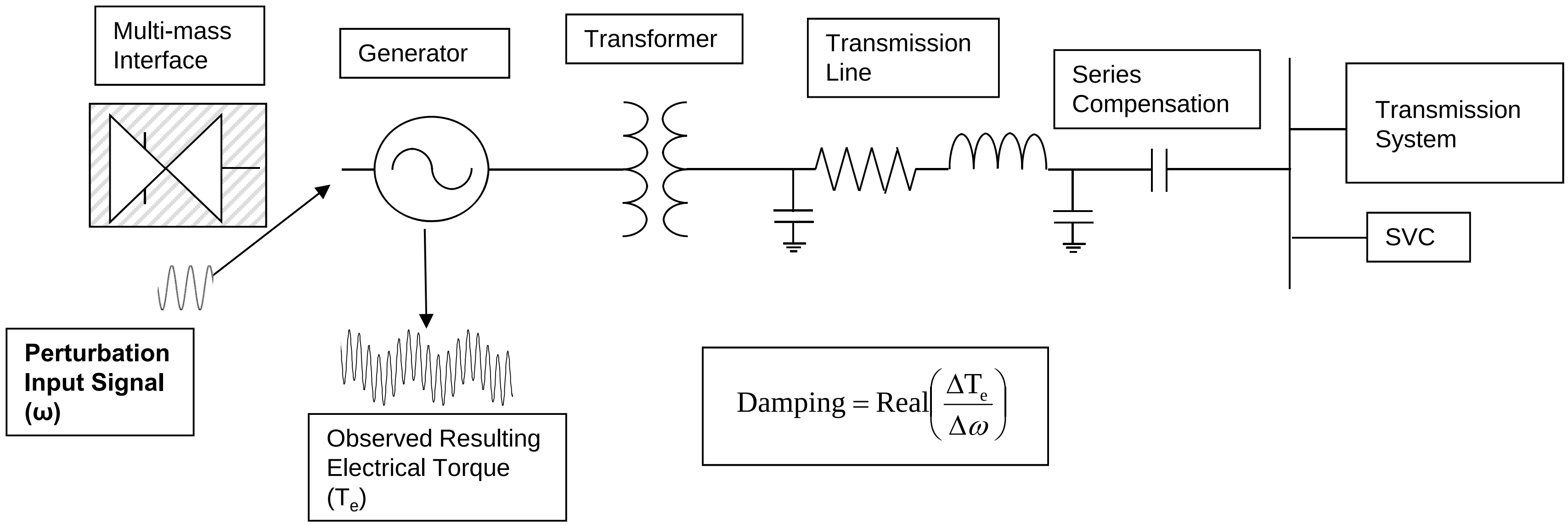
where :

In : Harmonic current generated from TCR
Zt : Impedance of coupling transformer
Zf : Impedance of filters and TSC
Zs : System impedance
Vln : Harmonic voltage at SVC bus
Vpn : Harmonic voltage at high voltage bus
n : Harmonic number

Subsynchronous Torsional Interaction Analysis

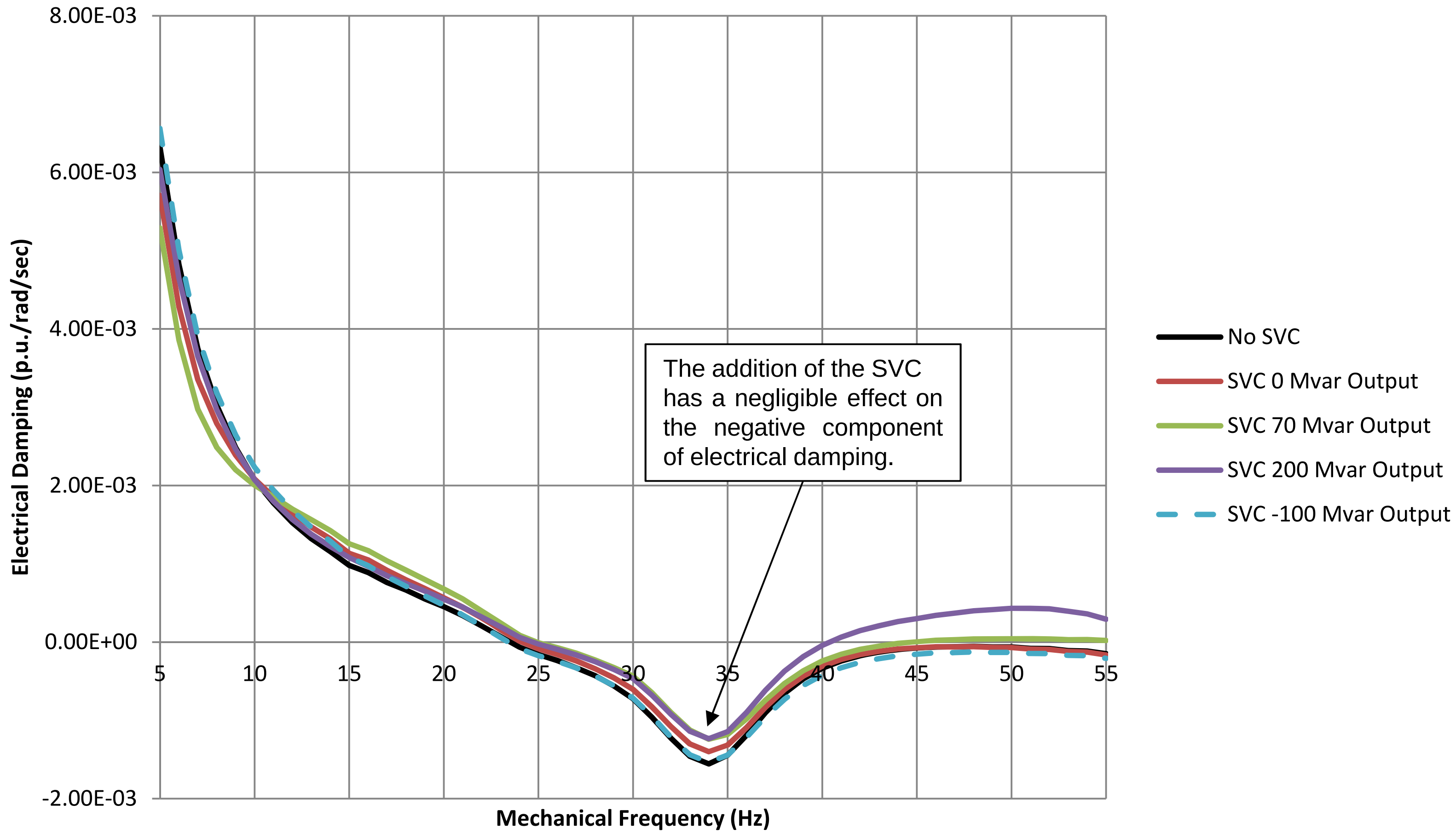
- Turbine generators have torsional modes of oscillation.
  - Steam turbines have the least mechanical damping (D_m), especially at light load.
  - Gas turbines have higher D_m
- Torsional stress caused by:
  - Impact loading: faults, switching, trips
  - Unstable torsional interactions with the system (SSR, SSTI)
- Sub-synchronous torsional modes (mechanical), below 60 Hz, of a generator can interact with the electrical system to which the generator is connected and result in torsional oscillations that are self sustaining or growing. These oscillations can lead to unstable conditions and can be damaging to the generator shaft system.
- Sub-synchronous torsional interactions can be identified by examining the electrical damping torque per unit of generator velocity.
- Positive electrical damping indicates that the electrical system will help to stabilize torsional oscillations and negative electrical damping indicates the electrical system will tend to destabilize torsional oscillations.
- A perturbation analysis can be used to identify sub-synchronous generator oscillations that could result in destabilizing electrical damping.

Illustration of the Perturbation Method



$$\text{Damping} = \text{Real}\left(\frac{\Delta T_e}{\Delta \omega}\right)$$

Electrical Damping With and Without SVC
N-6 Condition Cases

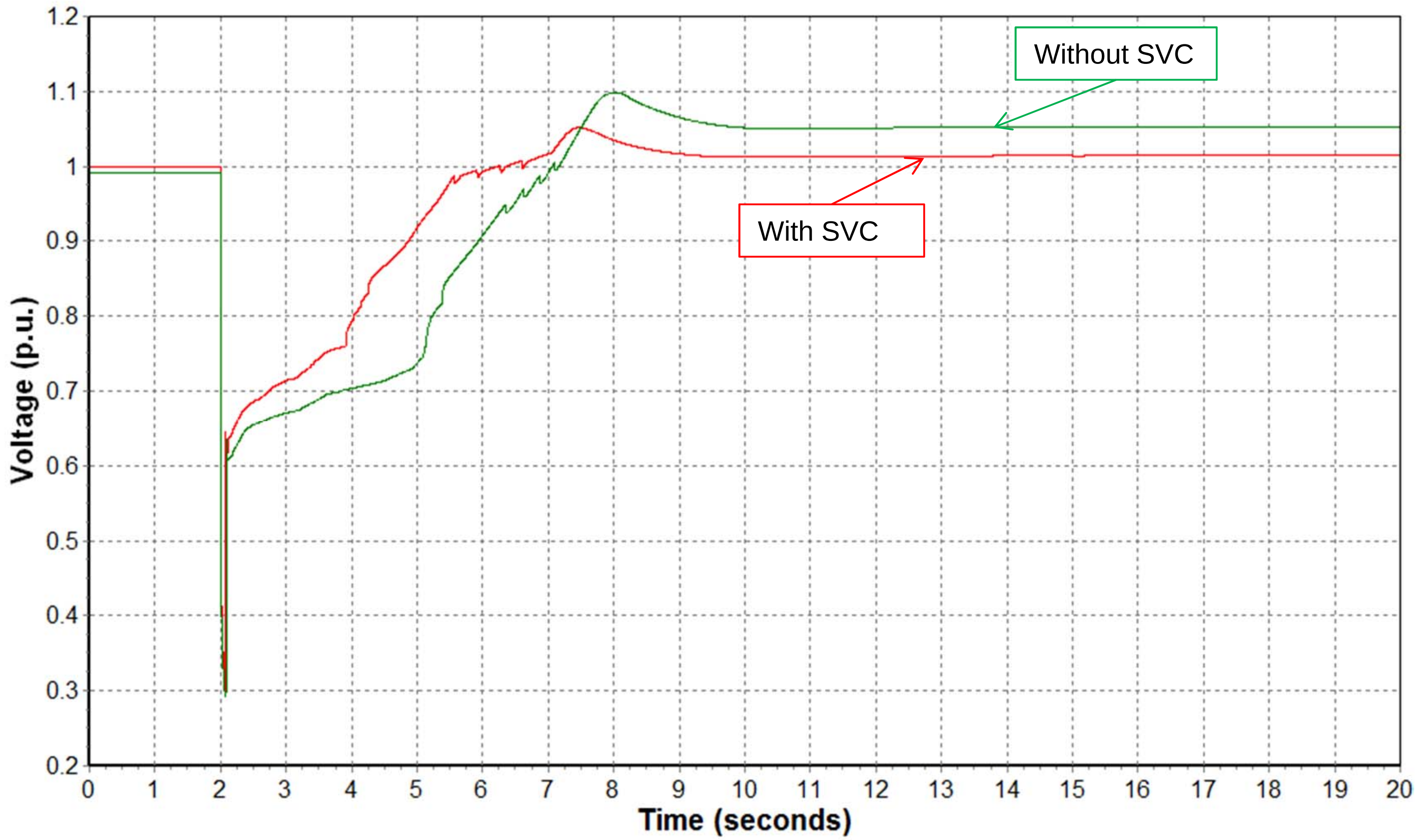


Dynamic Performance Analysis

- Verify that the SVC controls the system dynamic performance during system disturbances such as major faults
  - 5 to 20 seconds time-frame (PSLF/PSSE)
    - SVSMO1U1 model
  - Examine different loading conditions
  - Examine various operating conditions
- Can be performed in pre-bid stage to assist in rating and placement of FACTS device.

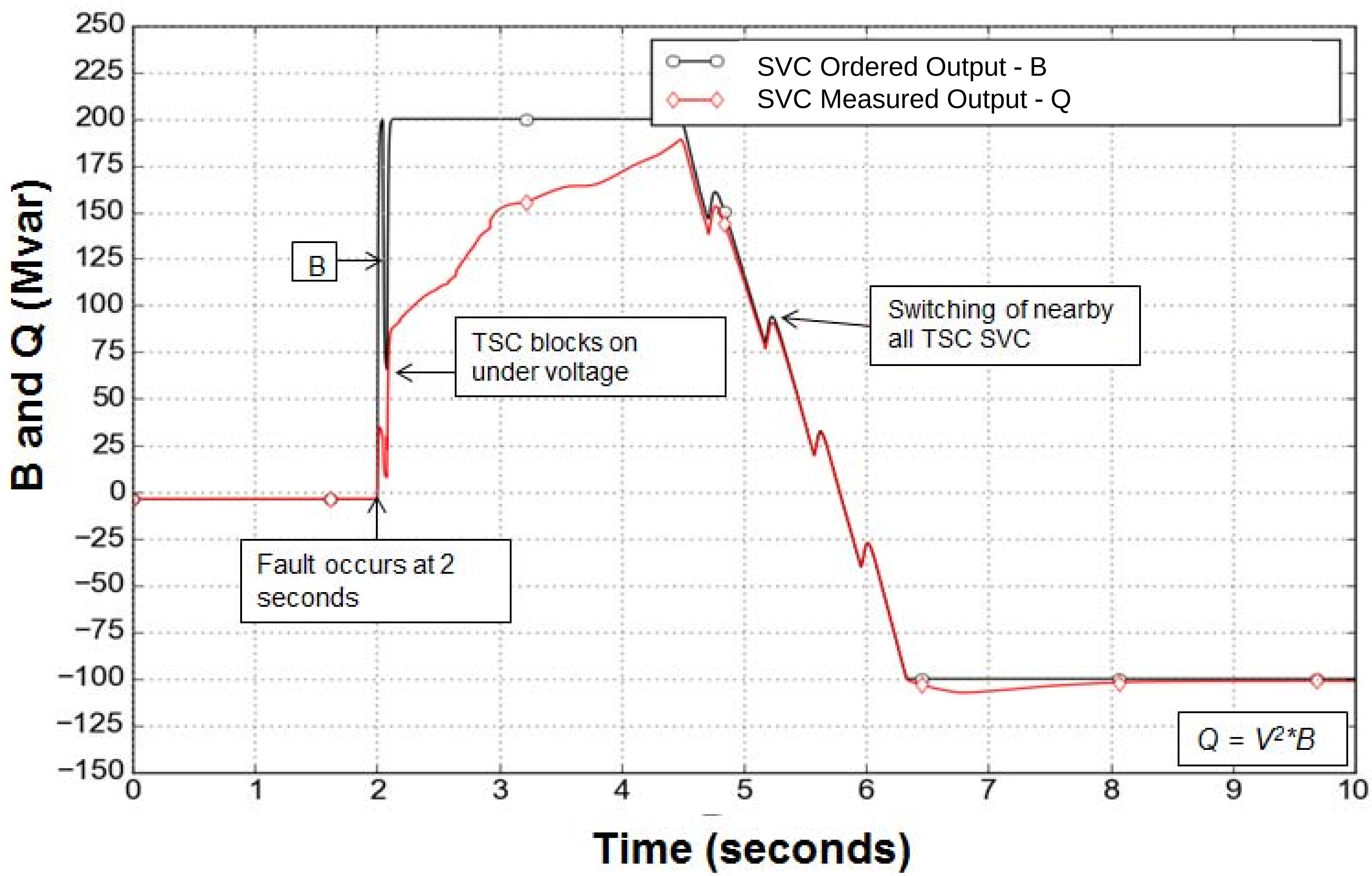
Dynamic Performance Analysis Results

Voltage at SVC bus in response to a 3LG fault at a remote bus



Dynamic Performance Analysis Results

SVC output in response to a 3LG fault at a remote bus



MITSUBISHI ELECTRIC
Changes for the Better

Thank You for Your Attention