CONVERSATORIO :

Junio 17

Colombia

Sistemas HVDC

SESIÓN 3 :
Estado del arte en Metodologías y modelos para HVDC

HVDC Modelling for Project Planning Studies

Modelado HVDC para estudios de planificación de proyectos

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Un evento: Colombia | Universidad Pontificia Bolivariana | 50 años Ingeniería Electrónica | 70 años Ingeniería Eléctrica | isa CONEXIONES QUE INSPIRAN

HVDC Planning Studies

- Feasibility Studies
- Steady State Power flow Studies
  - AC system upgrades
  - Voltage stability
  - Reactive power management
  - Special Protection Scheme requirements
- Transient stability assessment
  - Impact on AC system transient stability
  - Control requirements
  - Dynamic reactive power requirements
  - Frequency/inertia support
  - Special Protection Scheme requirements

HVDC Planning Studies

- Technology studies
  - In order to identify capabilities and limitations of new technologies
  - What to ask/expect from a manufacturer
- AC system harmonic evaluation
  - Harmonic impedance profile
  - Background harmonic measurements
- Cost evaluation
- Site selection
- Environmental impact assessment

Challenges in HVDC Planning

- Multiple HVDC options (monople, bipole, etc.)
- Multiple technologies (LCC or VSC)
- Multiple converter technologies for VSC (half bridge, full bridge, hybrid)
- No manufacturer is selected
- Performance and system impact need to be evaluated through studies

HVDC Simulation models

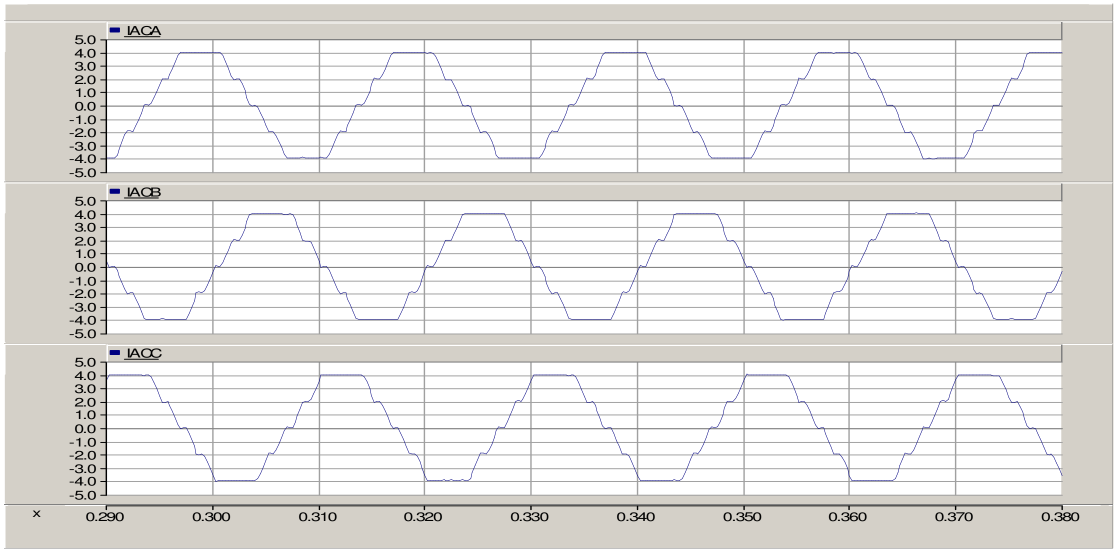
Motivation for Accurate Models

Accuracy of system study results rely on the accuracy of the models/data used to perform the study!

- This is very important when performing system studies:
  - Transmission systems are planned, designed and built on the basis of such studies
  - If study results are inaccurate due to “bad” models, implications could include:
    - Cost – system is over-designed e.g. too many synchronous condensers installed, unnecessary reactive power capabilities
    - Reliability – system is under-designed e.g. too few synchronous condensers installed – may lead to system instability or load shedding

Simulation Models

- EMT Models
  - Detailed converter model including switching logics
  - Detailed controllers
  - Frequency dependent modelling of DC transmission



Simulation Models

- Transient Stability Models
  - Approximated models (fundamental frequency positive sequence)
  - PI section models for DC transmission system
  - Controllers may or may not be modeled in detail

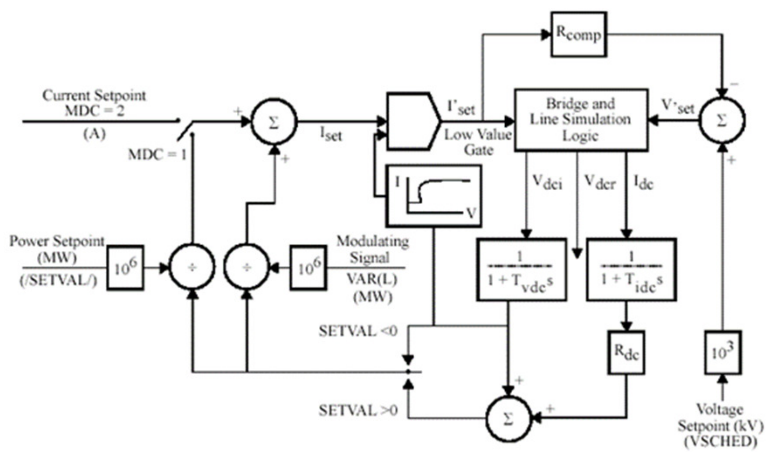


Figure 18-4. CDC4 dc Transmission Control Arrangements

Source: PSSE Manual

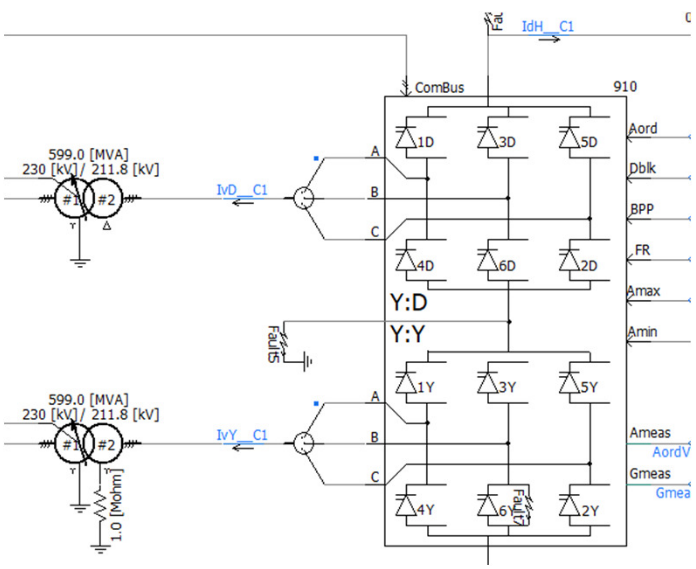
Procedure adapted by TGS

1. Develop a generic EMT simulation model
2. Tune the controllers to get an acceptable performance at the min/max short circuit strengths at the terminals
3. Select a suitable transient stability model
4. Benchmark the transient stability model against the EMT model
5. Perform system studies using benchmarked transient stability model

EMT Models for Planning Studies

- Converter Models

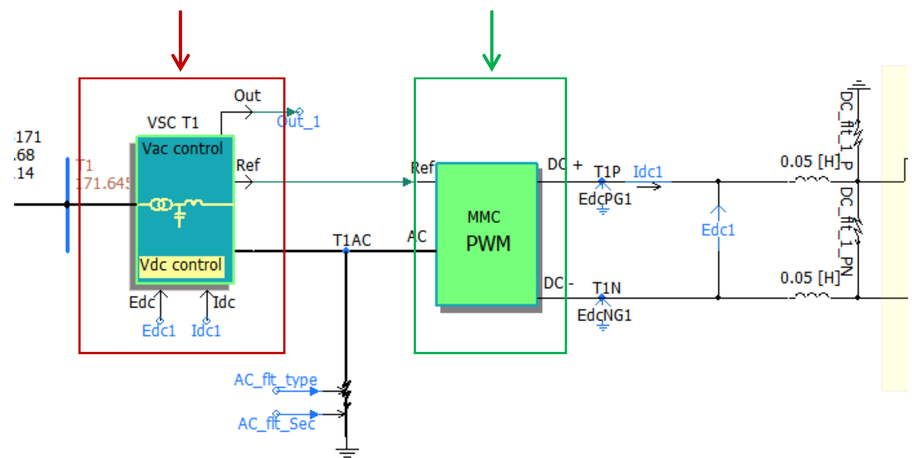
12 pulse thyristor bridge for LCC HVDC



MMC converter model for VSC HVDC

Converter transformer and Main AC breaker

MMC Valves and firing logic



EMT Models for Planning Studies

- Controllers

LCC HVDC

- Rectifier current/power controller
- Inverter extinction angle/DC voltage controller
- Inverter current margin controller
- Voltage dependent current order limiters (VDCL)
- DC fault clearing logics (e.g. forced retard)
- Thyristor firing logic

VSC HVDC

- Active power/DC voltage controller
- Reactive power/AC voltage controller
- Dynamic reactive current injection
- Islanded mode controllers
- Inner d-q current controllers
- Converter current/voltage limiting logics
- DC fault clearing logics

EMT Models for Planning Studies

- Controllers

Common Controllers

- Phase locked loop (PLL)
- Frequency controllers
- Power oscillation damping controllers
- Sub-synchronous damping controller
- Run ups and run backs (Special Protection Systems)

Typical Transient Stability Models

- Response-type
- No DC voltage or current controllers – because of small time constants
- Assumes instantaneous jumps in dc voltage and current
- All dc injections based solely on steady state dc equations
- Model is programmed to recover from faults in a pre-set manner

Typical Transient Stability Models

PROS	CONS
• Can be run using the large ½ cycle time-step used in most transient stability applications	• Requires user to enter many parameters, such as voltage and current ramp rates • Different power flow and system conditions may require different sets of parameters • Can be very time-consuming • Especially for inverter-side faults and commutation failures, not very accurate • DC transmission L-R-C dynamics missing

Transient Stability Models -Possible Solutions

- Hybrid simulations
  - HVDC and a small part of the AC network are modeled in an EMT environment and combined with a large network in a transient stability environment
  - Large modelling effort
  - Time taken for simulations (usually 100s of simulations)
  - Interfacing issues
  - Validations???

Transient Stability Models -Possible Solutions

- Two-time step simulations
  - HVDC is run at very small time steps (e.g. 50 us)
  - Rest of the system is run at regular time steps (half or quarter cycles)
  - HVDC model is first validated against an EMT model at maximum and minimum system strengths expected at the terminals (tuning & validations)
  - Any number of HVDC systems can be modeled.
  - No burden on the time taken for the transient stability analysis (fast and low cost solutions)

Transient Stability Models -Possible Solutions

- Two-time step simulations
  - TGS has used this approach for many projects and manufacturer detailed model developments
    - 2T LCC HVDC model (in PSSE & PSLF)
    - 3T LCC HVDC model (in PSSE & PSLF)
    - 2T MMC VSC HVDC model (in PSSE, PSLF and DIgSILENT)
      - Half bridge & Full bridge converters
      - Monopole & Bipole configurations
      - DC faults
        - Cleared using fast DC breakers
        - Cleared using AC breakers + mechanical DC breakers
        - Cleared using controlled fault clearing logics
    - DC grid model (with FB VSC converters & LCC converters)
    - MMC STATCOM model

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Example: 2T LCC Model

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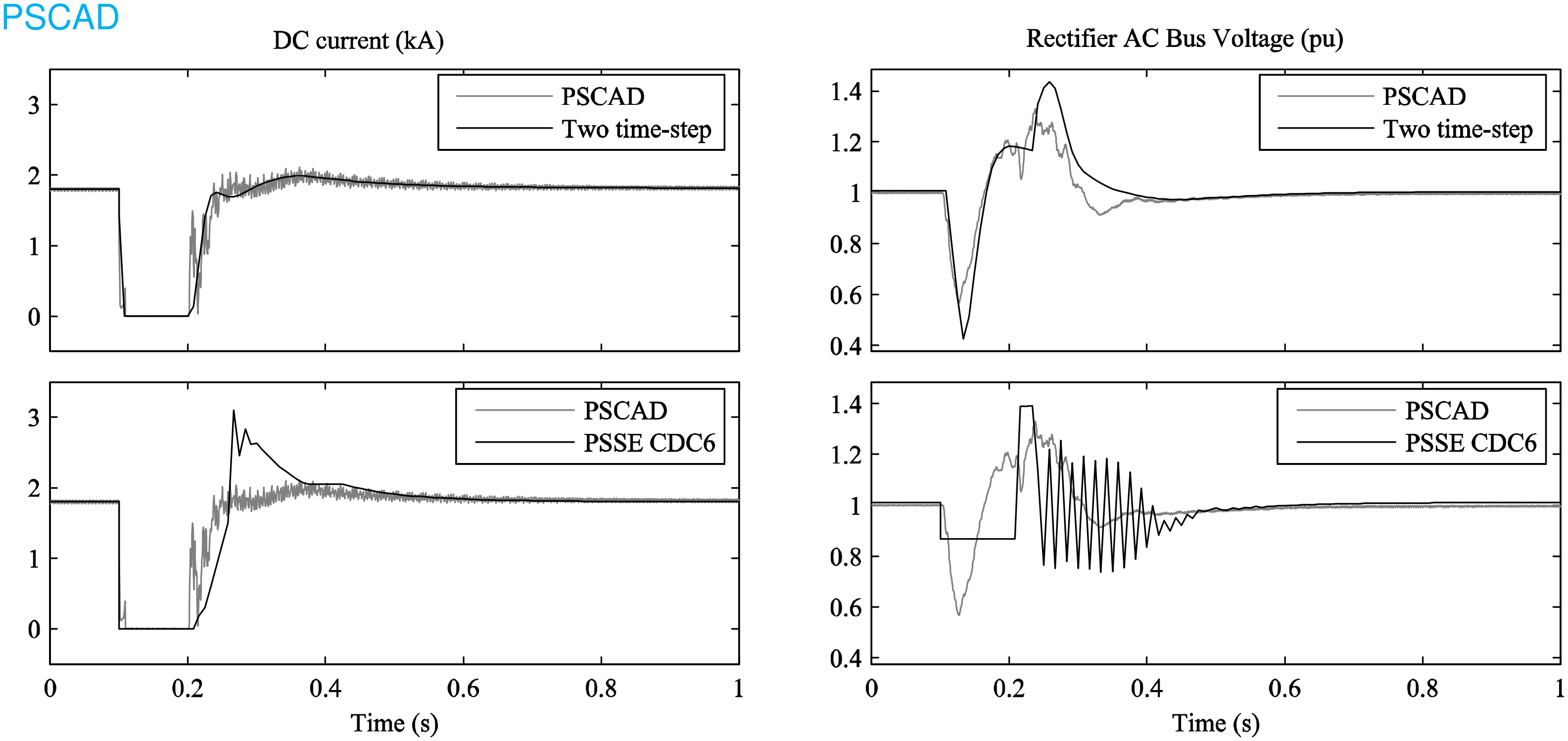
Comparison of performance of PSSE model against PSCAD

3PH Fault at Rec

3PH Fault at Inv

Two-time step

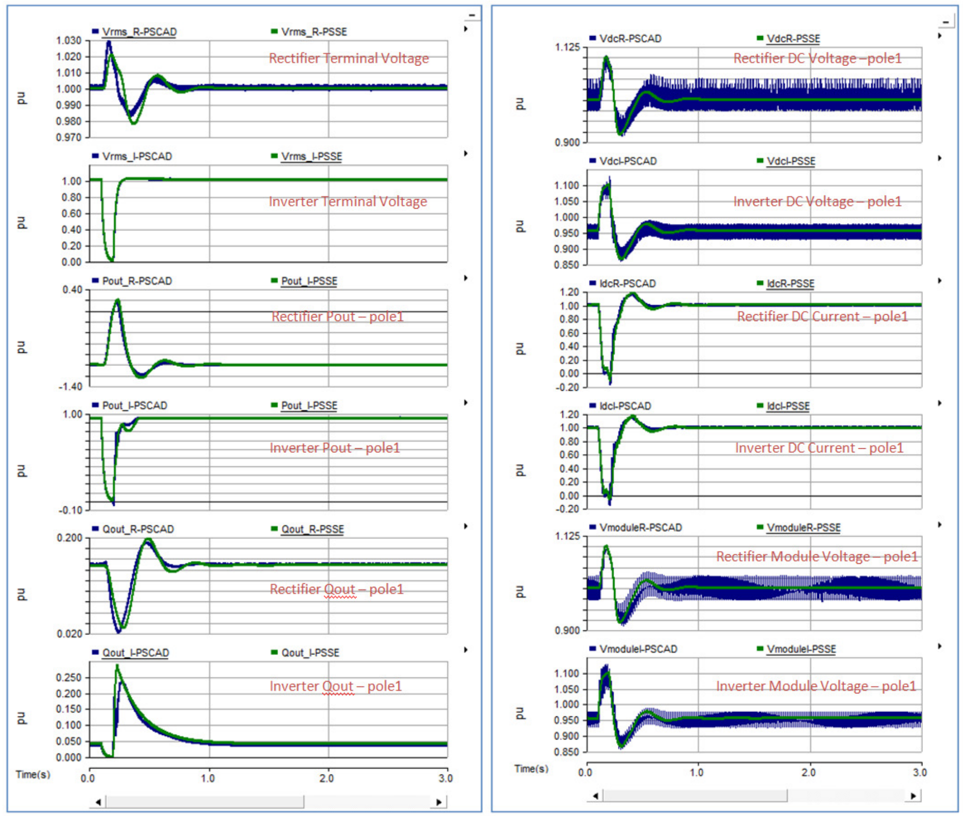
Response type



Example: 2T MMC VSC

- Three phase ac faults at the terminals (fault ride through capability)

Comparison of performance of PSSE model against PSCAD



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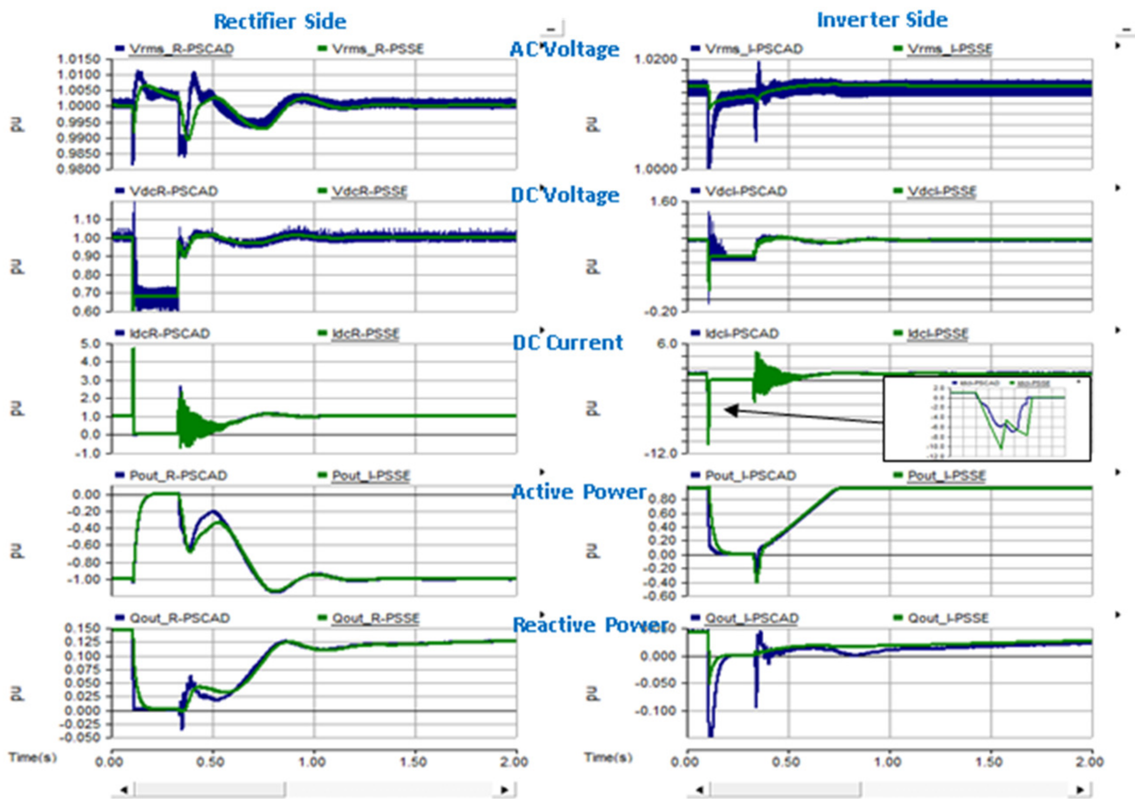
Example: 2T MMC VSC

- Inverter Side DC fault Cleared by a Fast DC Breaker

Comparison of performance of PSSE model against PSCAD



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DC Grid Example

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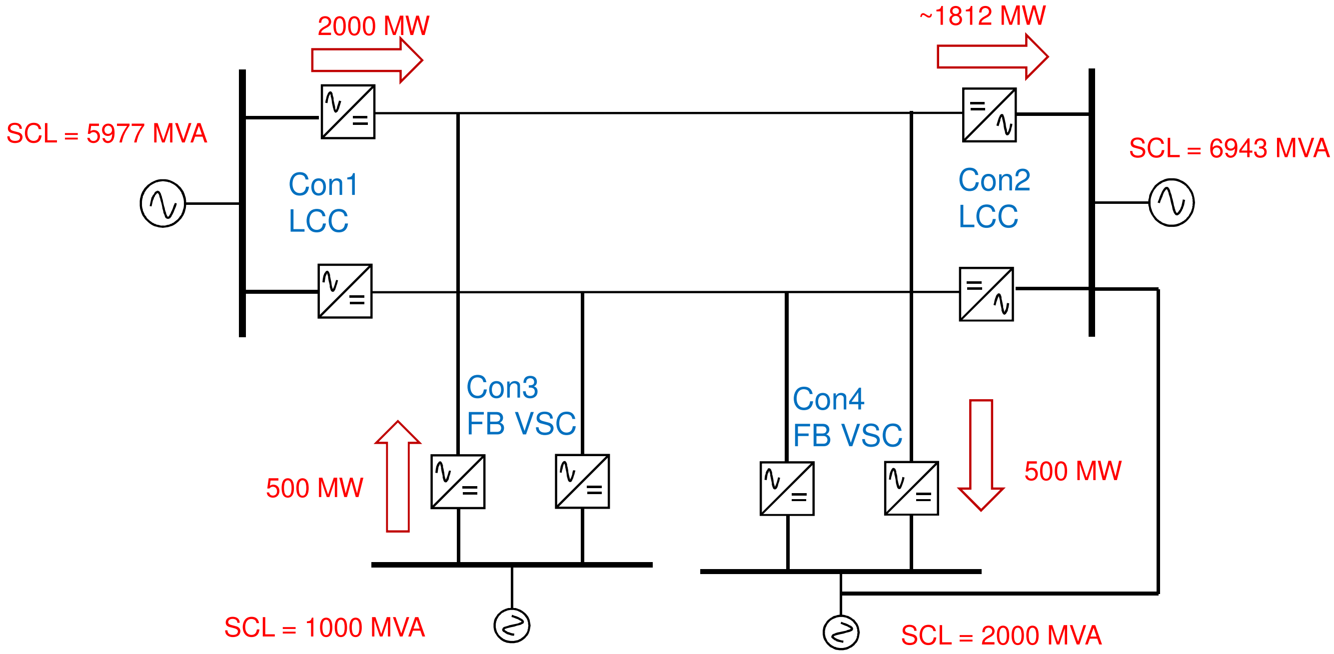
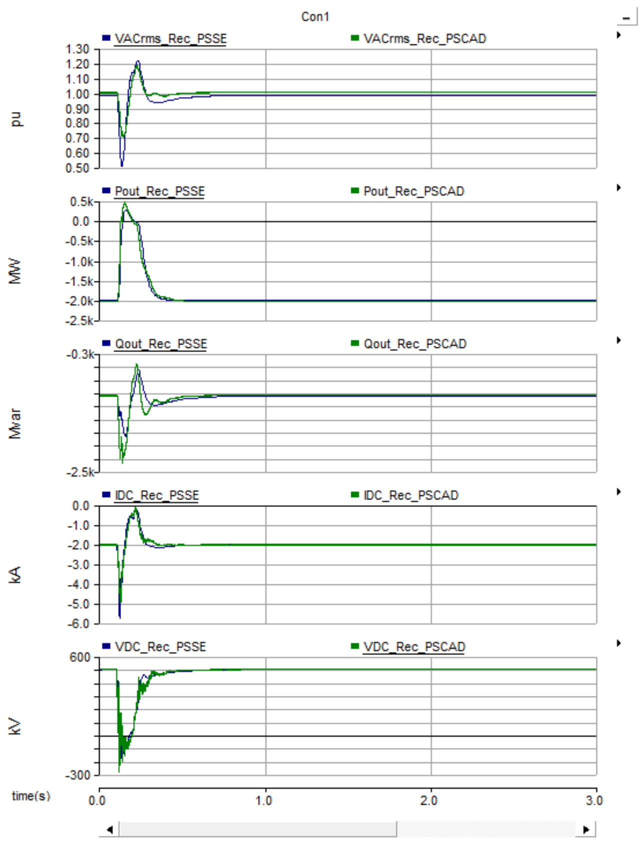
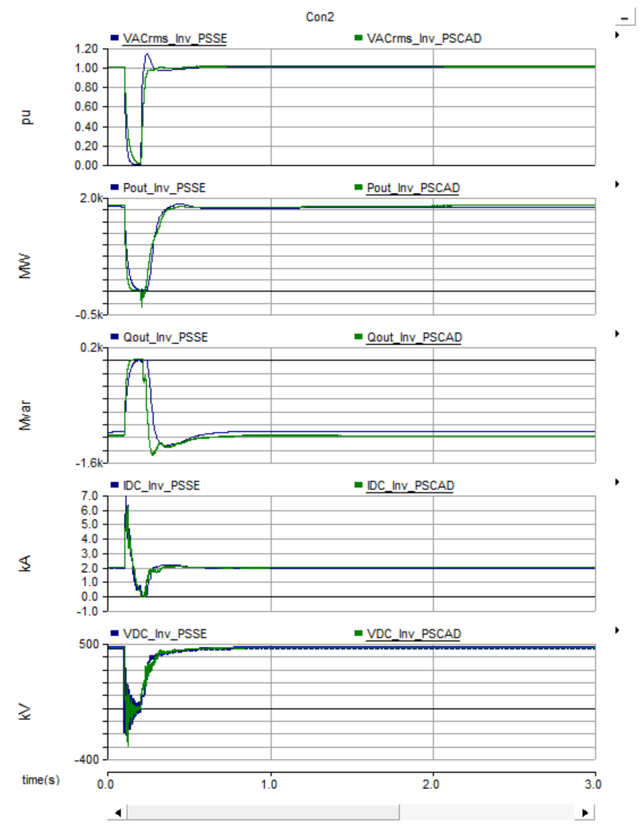


This model was used for Manitoba Hydro Bipole-3 VSC tapping studies

AC Faults

Solid AC fault at Con2 (inverter) – LCC Plots





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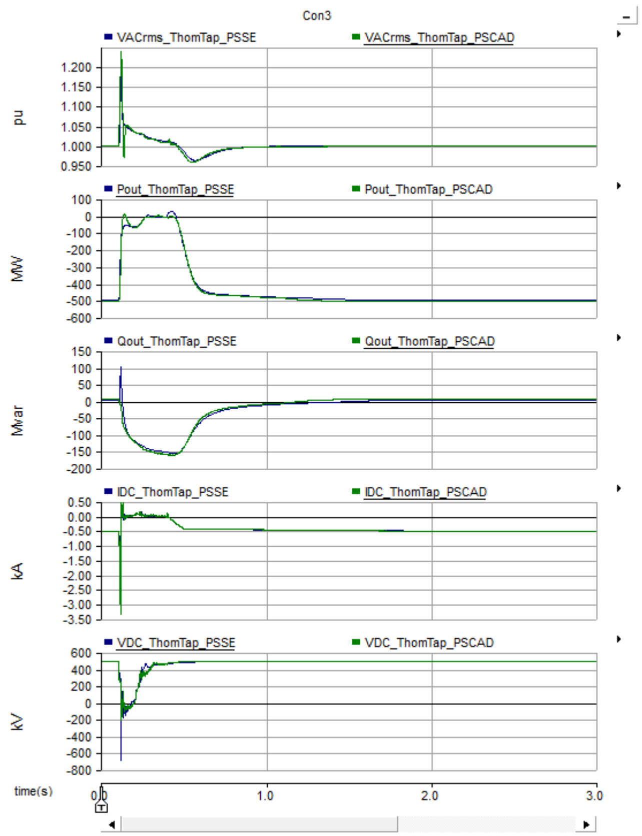
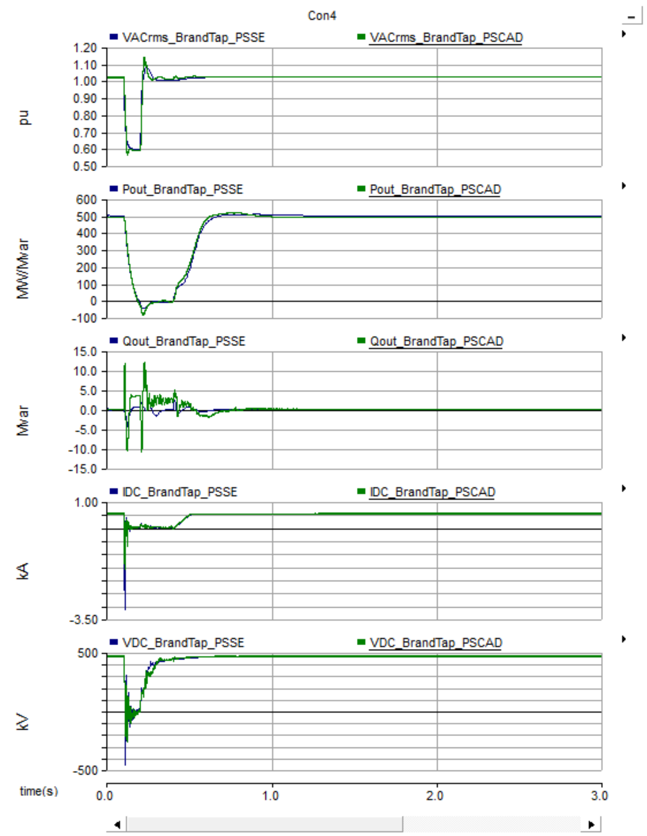
AC Faults

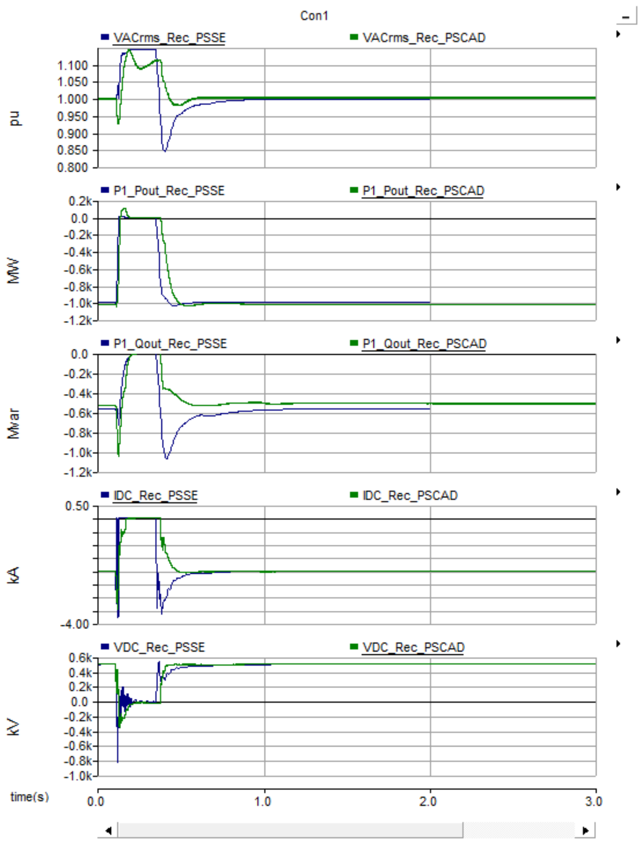
Solid AC fault at Con2 (inverter) – VSC Plots

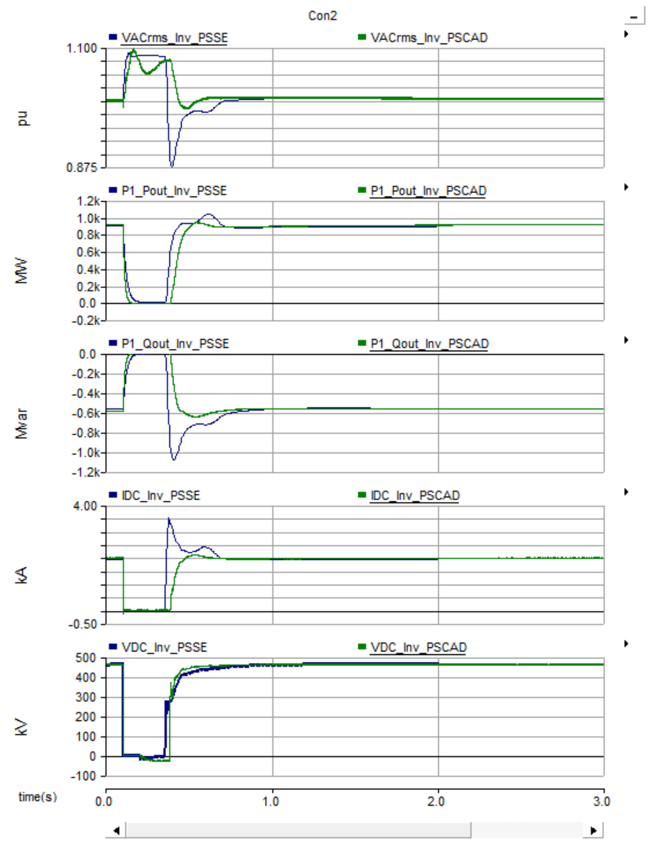




DC Faults

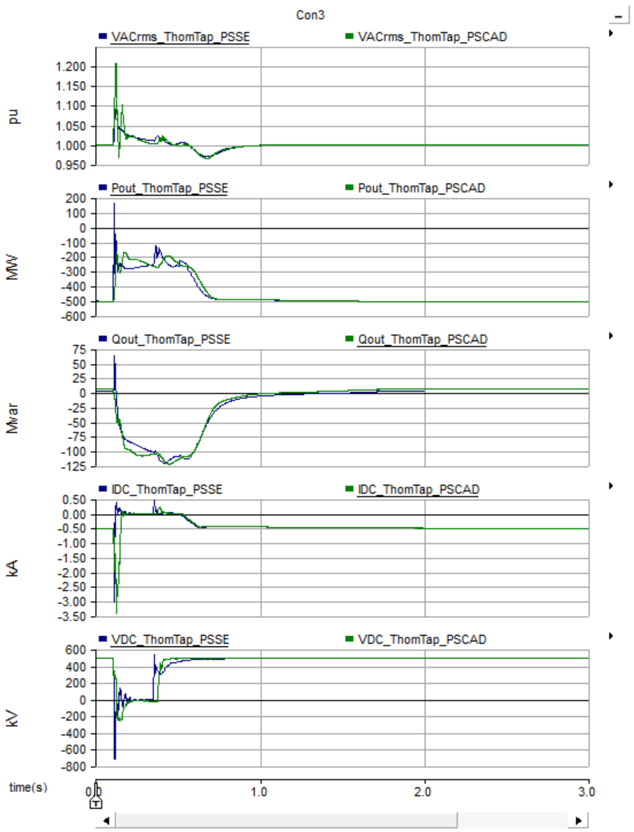
DC fault at Con2 – LCC Plots

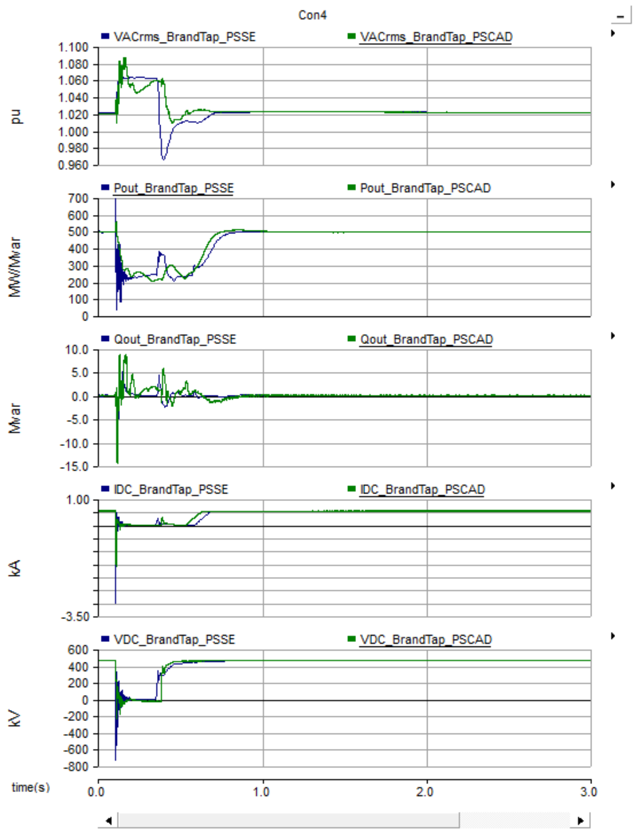




DC Faults

DC fault at Con2 – VSC Plots





Summary

- It is very important to model the accurate behavior of HVDC systems for planning studies.
  - Determine system requirements
  - Determine HVDC performance requirements – to be included in the HVDC specification or to evaluate the manufacturer's designs
- Proper models should be used for proper applications (EMT or TS)
- TGS has adapted "two-time-step" approach for transient stability analysis
  - Accurate results
  - Model set up and simulation is easy
  - Large number of simulations can be done in a short time

Gracias