MANITOBA·HVDC RESEARCH CENTRE

Development

Engineering

Innovation

Since 1981

PSCAD

Poland

PSCAD Seminar

J.C. Garcia, W. Wiechowski
Manitoba HVDC Research Centre
Winnipeg, Manitoba, Canada

MANITOBA·HVDC RESEARCH CENTRE

Applications of EMT Type Programs in Smart Grids and Distributed Generation

Manitoba HVDC Research Centre

MANITOBA-HVDC RESEARCH CENTRE

Manitoba HVDC Research Centre

- Winnipeg, Manitoba, Canada
- Software Group
- Research Laboratories
- Classroom
- 40+ Staff Members

PSCAD

MANITOBA HVDC RESEARCH CENTRE

Manitoba HVDC Research Centre

- Commercial Products
  - PSCAD®/EMTDC™
  - DC Line Fault Locator System
  - Ice Vision - Ice Detection System for AC Ice Melting Program
- Training
  - General Power Systems
  - PSCAD
- Engineering Services
- Research Services

PSCAD/EMTDC Users

- Our users are utilities, manufacturers, industrial research centers, and consultants including three large HVDC equipment manufacturers
  - ABB, Siemens, Areva, Toshiba, Mitsubishi, Hitachi, Fuji, and many others
- More than 2,000 professional and 30,000 educational licenses, in 76 countries worldwide

Smart Grids & DG

A popular definition of Smart Grids

"Aggregate of multiple networks with multiple operators employing varying levels of communication and coordination. Smart grids increase the connectivity, automation and coordination between these suppliers, consumers and networks that perform either long distance transmission or local distribution tasks."

A smart grid may include:

- "an intelligent monitoring system (communications) that keeps track of all electricity flowing in the system"
- "the capability of integrating renewable electricity such as solar and wind (DG)"

PSCAD & DG

Modernizing the grid to meet such requirements implies:

- A need for the revision on the distribution protection system
  - Sources of short circuit current (DG) where there was previously only load – Use of FCL's
- Studies on the penetration of DG in the network
- Power quality (harmonics introduced by the use of converters)

Fault Current Limiters

Challenge:

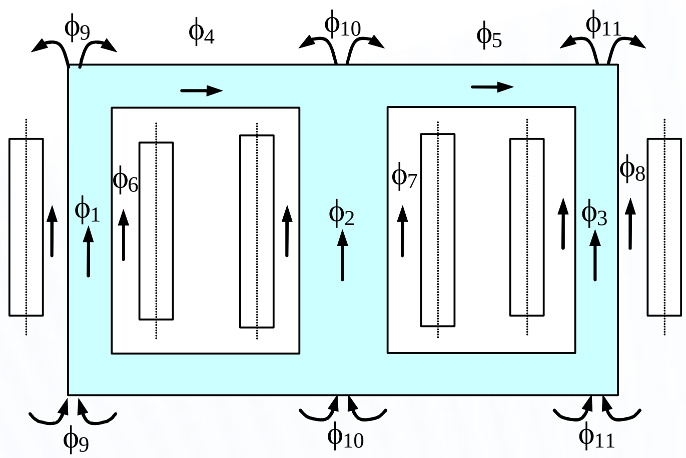
- Network reconfigurations and the introduction of DG can increase in short circuit levels

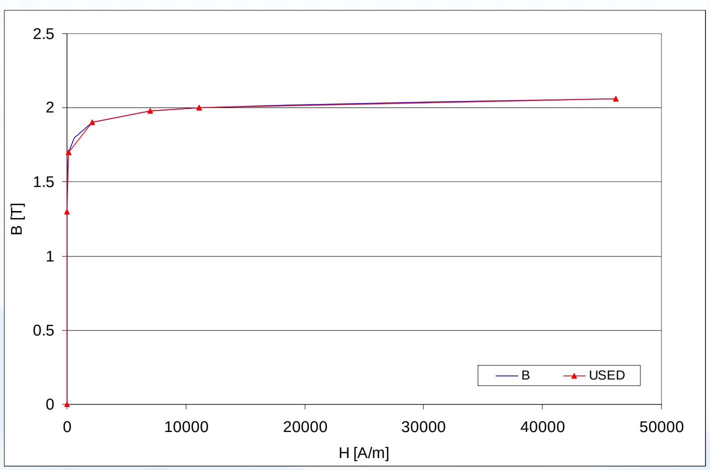
Solution(s):

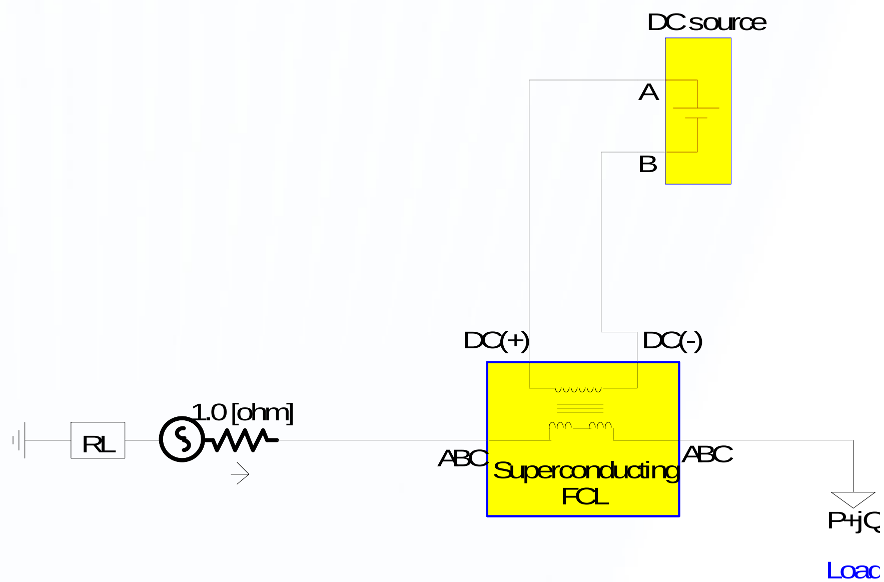
- Replace breakers and busbar equipment (too costly $$$)
- Introduce devices that limit the short circuit current:
  - One time use: resistors triggered by explosive mechanisms
  - Re-usable: Superconductor resistors, Magnetic devices (variable inductors)

Magnetic Fault Current Limiter

PSCAD implementation of a Super Conducting Fault Current Limiter



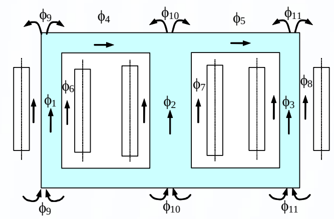




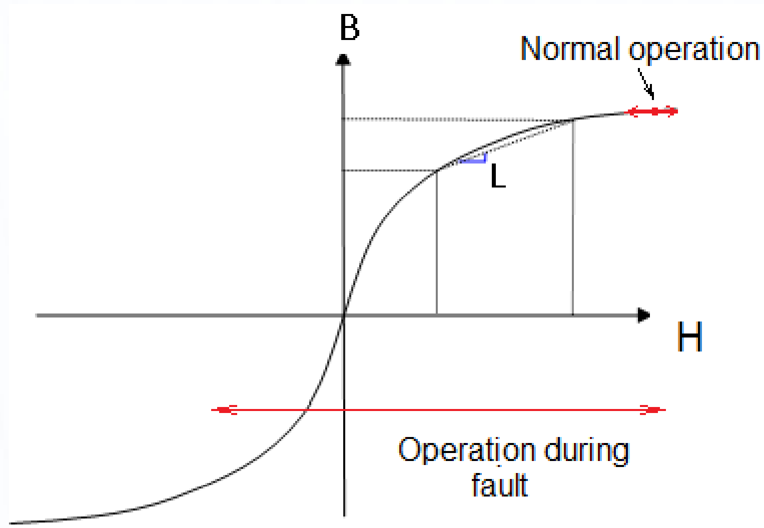
Fault Current Limiter

Need for reducing short circuit levels

- Requirement for small voltage drop during normal operation
- and large voltage drop during short circuit

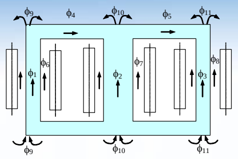


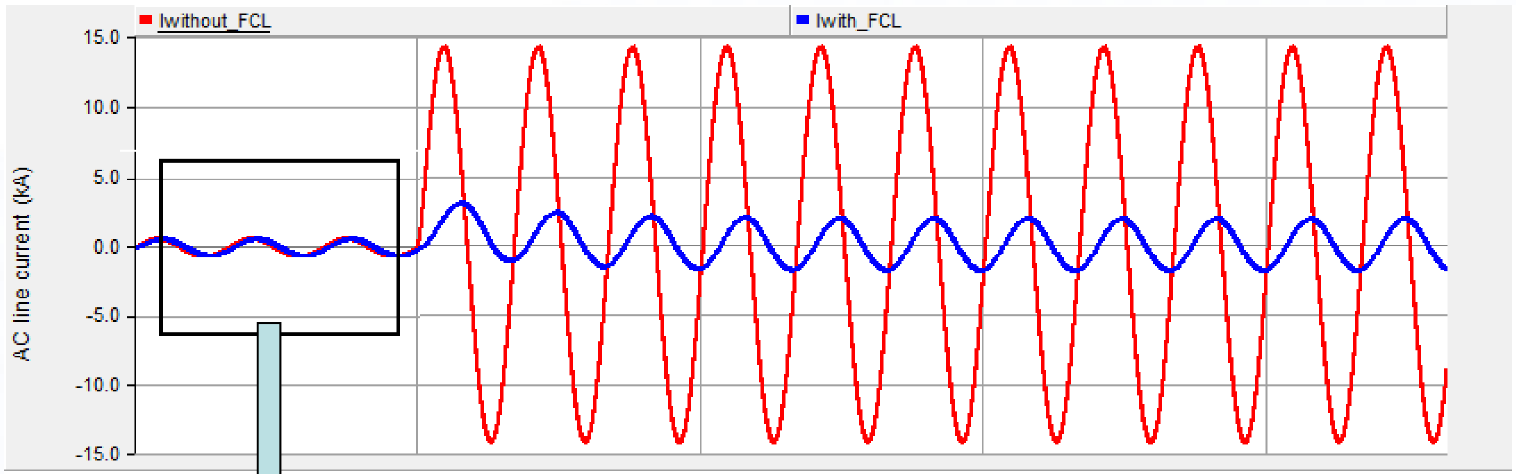
$$L = \frac{\mu A}{l} n^2$$

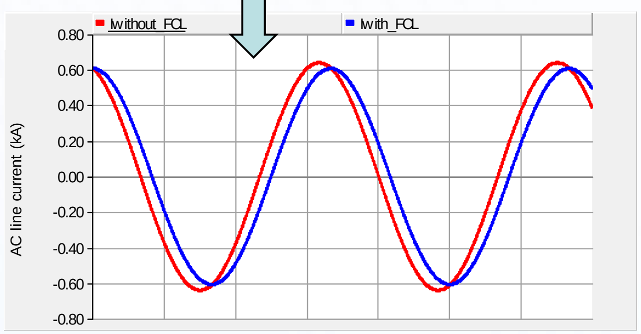


Fault Current Limiter

Need for reducing short circuit levels







- Requirement for small voltage drop during normal operation
- and large voltage drop during short circuit

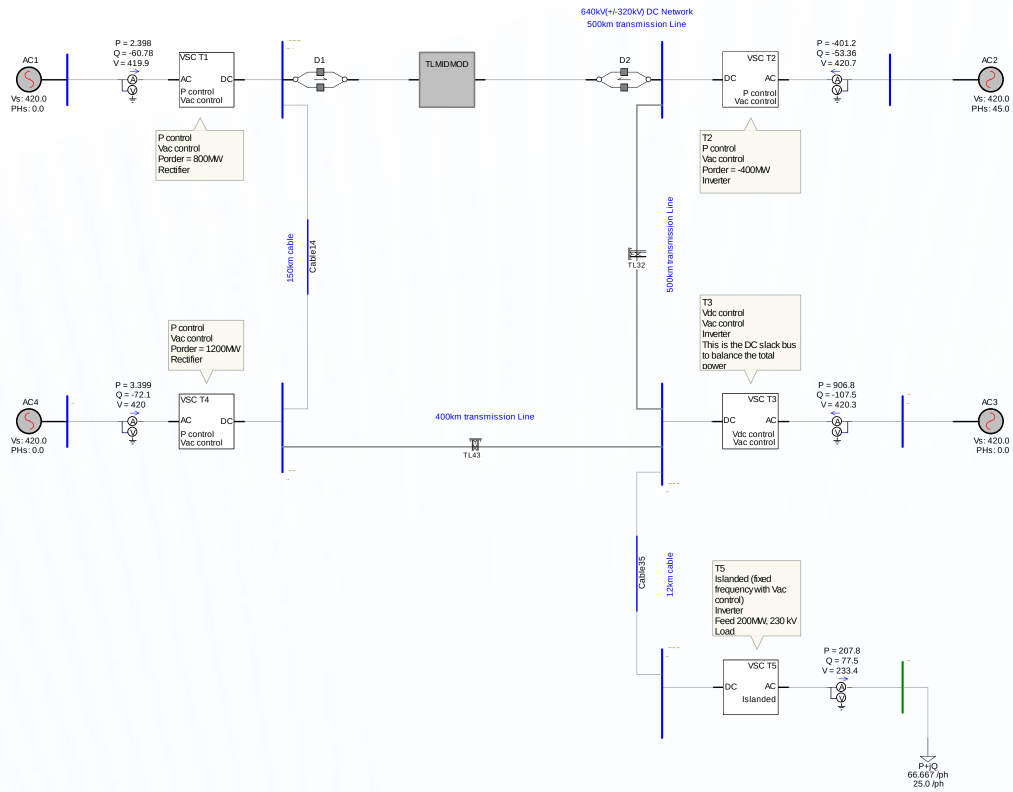
Large Scale Smart Grids

Smart Grid: “a grid that uses state of the art technology to re-route power in optimal ways to respond to a wide range of conditions”

When talking in large scale it means:

- Being able to control power flows in networks, FACTS, HVDC LCC, HVDC VSC
- To have the option of isolate trouble areas while minimizing the impact to the whole network – HVDC, ex: the blackout in eastern North America - Quebec

Multi-terminal VSC in PSCAD
Five-terminal example



Multi-terminal VSC in PSCAD
Five-terminal example

Advantages of VSC over LCC:

- Multi-terminal operation
- Decoupled control of P and Q. There is no-longer need for a source of reactive power
  - Can supply load centres

Disadvantages

- Not yet implemented
- Need for DC interrupting devices (DC breakers)

Multi-terminal VSC in PSCAD
Five-terminal example

Factors to be taking into account when modeling:
Development of control strategies, pole control and supervisory controls. Different control modes:

1. Real Power P
2. Reactive Power
3. AC Voltage
4. DC Voltage
5. Islanded Operation
   - Operation as an Statcom when islanded

Multi-terminal VSC in PSCAD
Five-terminal example

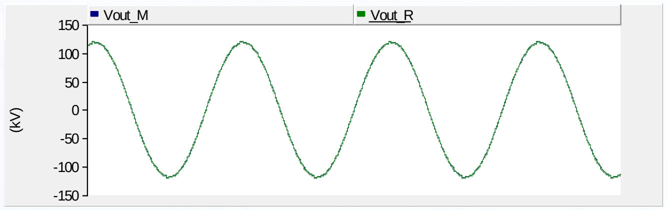
Current technologies

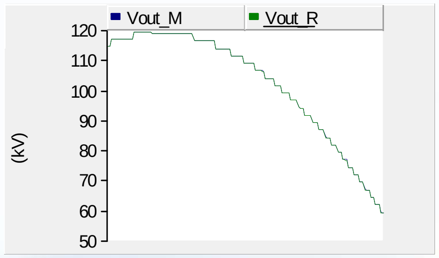
- PWM 2 and 3 level converters (ABB HVDC Light)
  - Moving towards MMC
- Modular Multilevel Converters (Siemens)
- Alstom VSC's (previously Areva's)

VSC in PSCAD: State of simulation technology

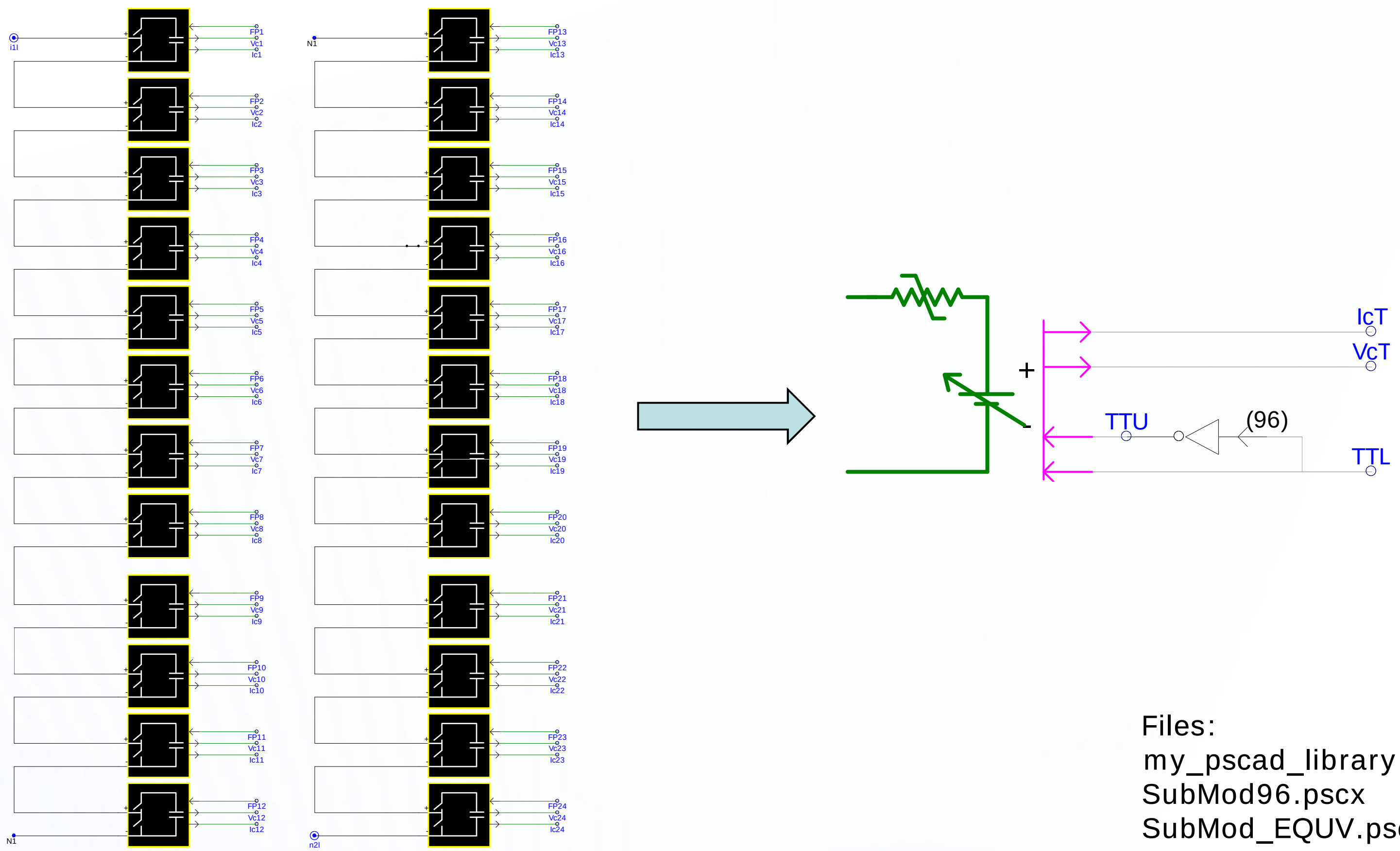
Modeling Multi-Level converters require modeling individually of each level.

- Large computational burden
- It creates the need for creating more computational efficient algorithms
- Current development of MMC model for PSCAD uses a time-varying Thevenin's equivalent of the converter
  - It is not an approximated interfaced model, it is equivalent to modeling the entire network



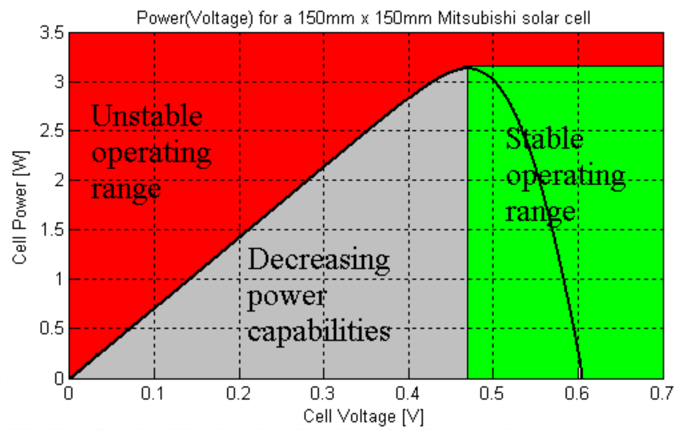


Thevenin's approach to MMC modeling

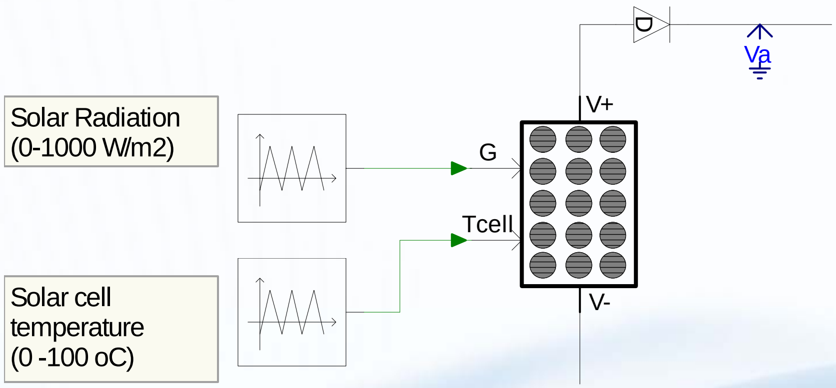


Files:
my_pscad_library.pslx
SubMod96.pscx
SubMod_EQUV.pscx

DG: PhotoVoltaics

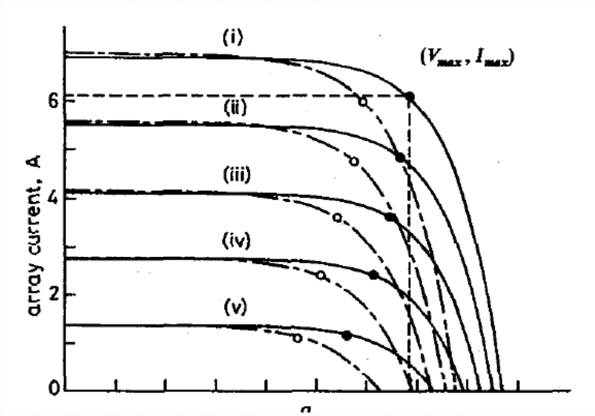


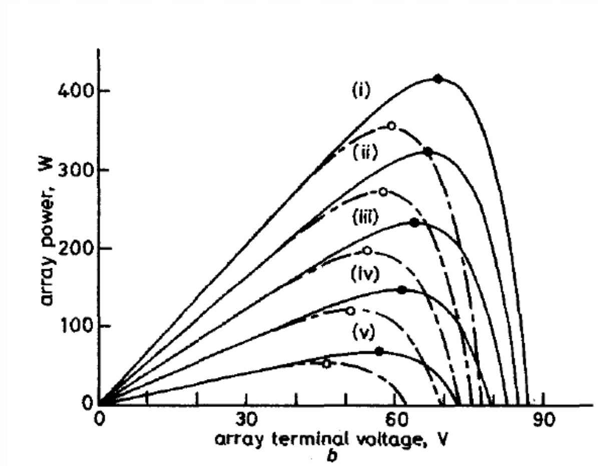
In the stable region if the output power is less than the input power, the remainder shows itself in an increased DC-bus voltage which causes a subsequent decrease in power input, creating an ultimately stable system without additional control mechanisms.



DG: PhotoVoltaics

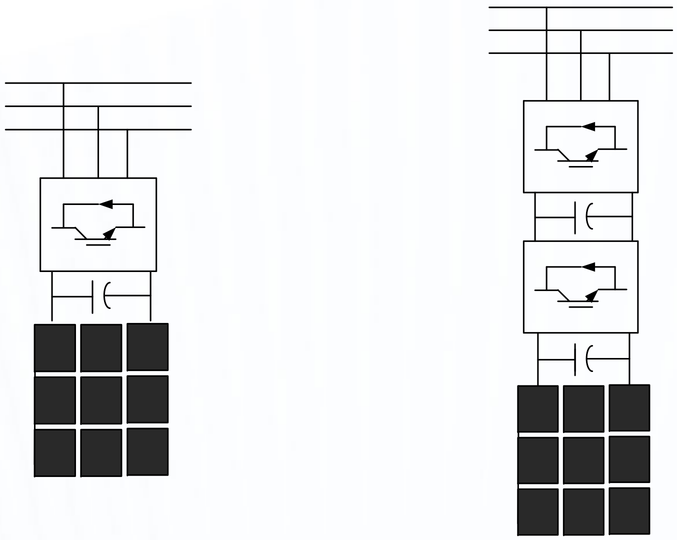
The goal is to operate the PV system in an stable fashion while delivering maximum power: Maximum Photo-voltaic Power Tracking (MPPT)





DG: PhotoVoltaics

Connection methods to the system



- **PSCAD is now used for a variety of ‘novel’ applications.**
    - Wind, DFIG, VSC Solar PV ……

However, basic ac system studies are still the most popular application of PSCAD.

- Lightning (insulation coordination)
- GIS switching – Very Fast Transients (VFT)
- Switching over-voltages (SOV,TOV)
- Breaker TRV
- Ferro resonance
- Other resonance issues (transformer , capacitor banks…)
- Protection and relaying related
- Motors and generators (starting, sub synchronous resonance..)
- Power quality

Post contingency analysis – What went wrong and how do we avoid such events.

Few Interesting (recent) applications:

1) Transformer Bushing failure in a power plant
2) System black start restoration studies
3) Fault current limiting devices
4) Protection

Transformer Bushing failure in a power plant

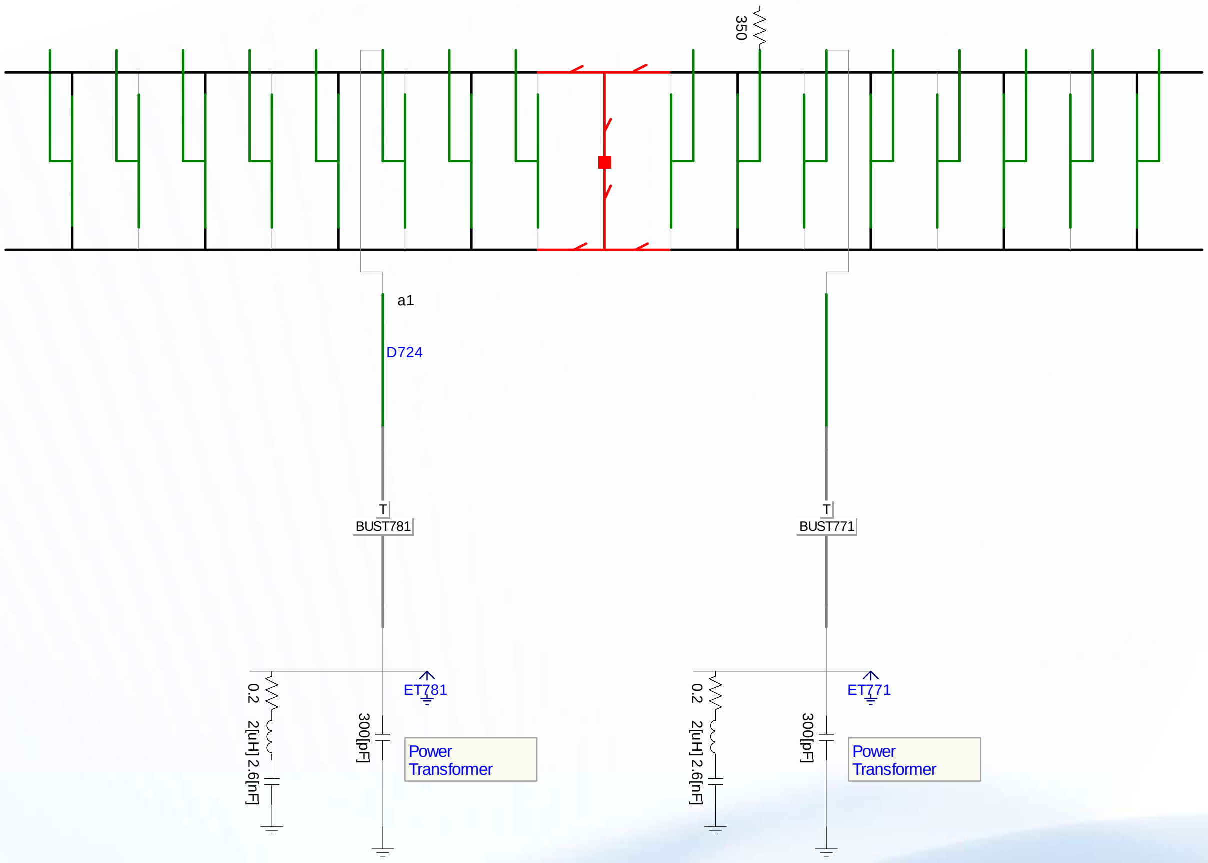
- Gas insulated bus-bars connect the GIS to the generator transformers.
- Number of transformers failed over a period of about 2 years.
- Perform apparatus inspections and perform engineering studies (simulations) to investigate the causes for the 380 kV transformer bushing failures.

Transformer Bushing failure in a power plant

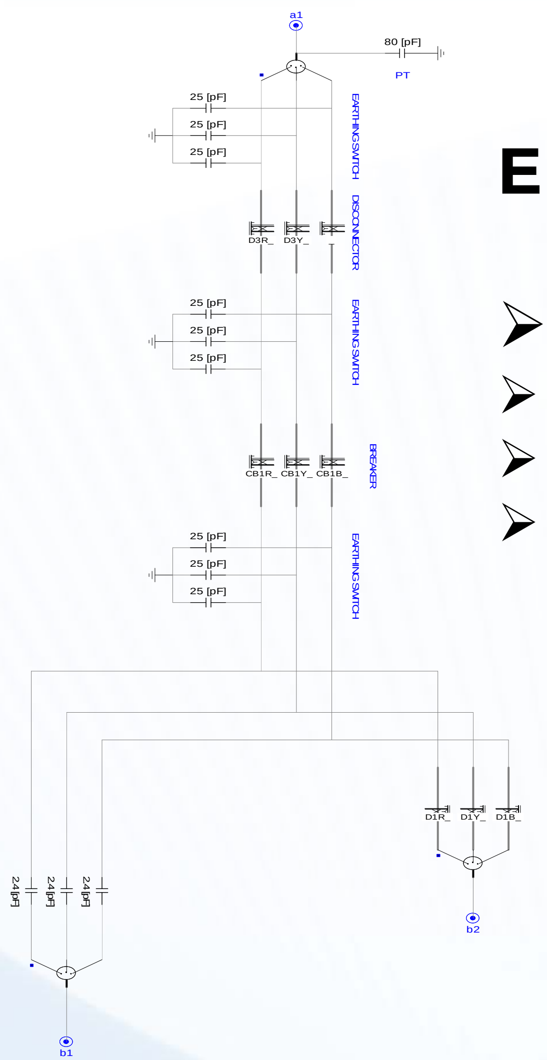
- Transformers are connected to the switching station through long GIB's.

Transformer Bushing failure in a power plant

PSCAD model of a GIS station – Investigating very fast transients (VFT)



Transformer Bushing failure in a power plant

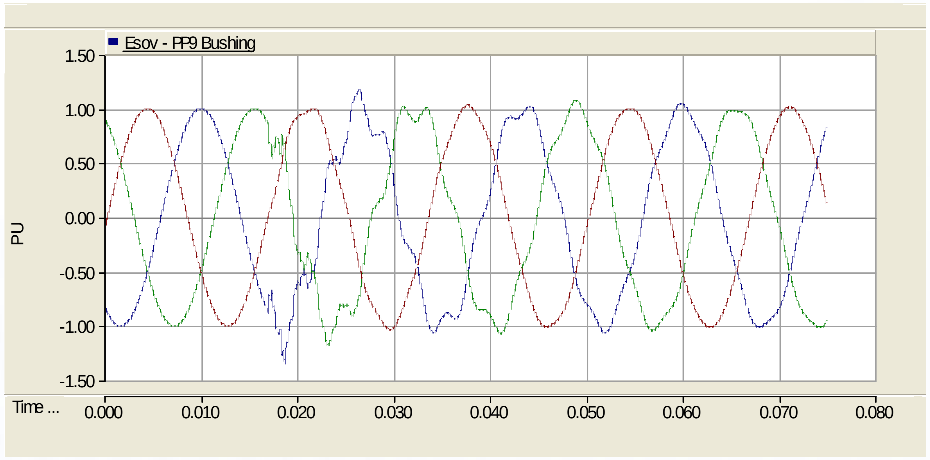


Electrical studies:

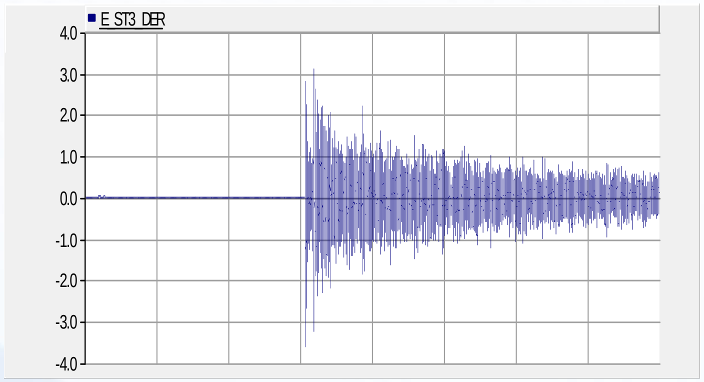
- Switching, and temporary over voltages
- Ferroresonance
- Harmonic impacts
- GIS Very Fast Transients.

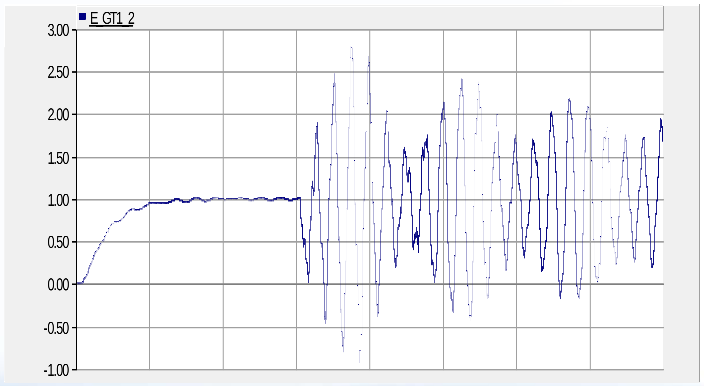
Transformer Bushing failure in a power plant

Switching transients



GIS switching related VFT - MHz range





MANITOBA HVDC RESEARCH CENTRE

System black start restoration studies

Getting a power system back into operation after 'black-out- is not an easy task and should be carefully planned (Black start restoration plans)

Some issues:

- Can we energize lines , transformers and loads through available generating units?

- System has very little damping due to low load. Resonance issues.

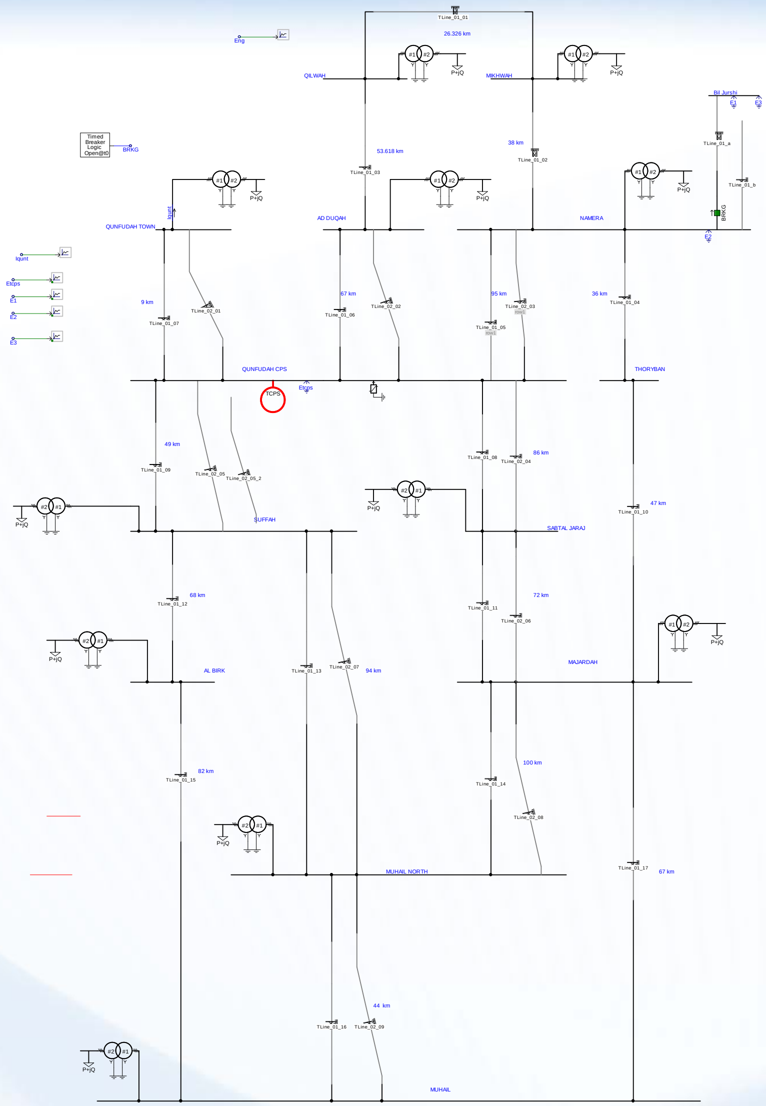
System black start restoration studies

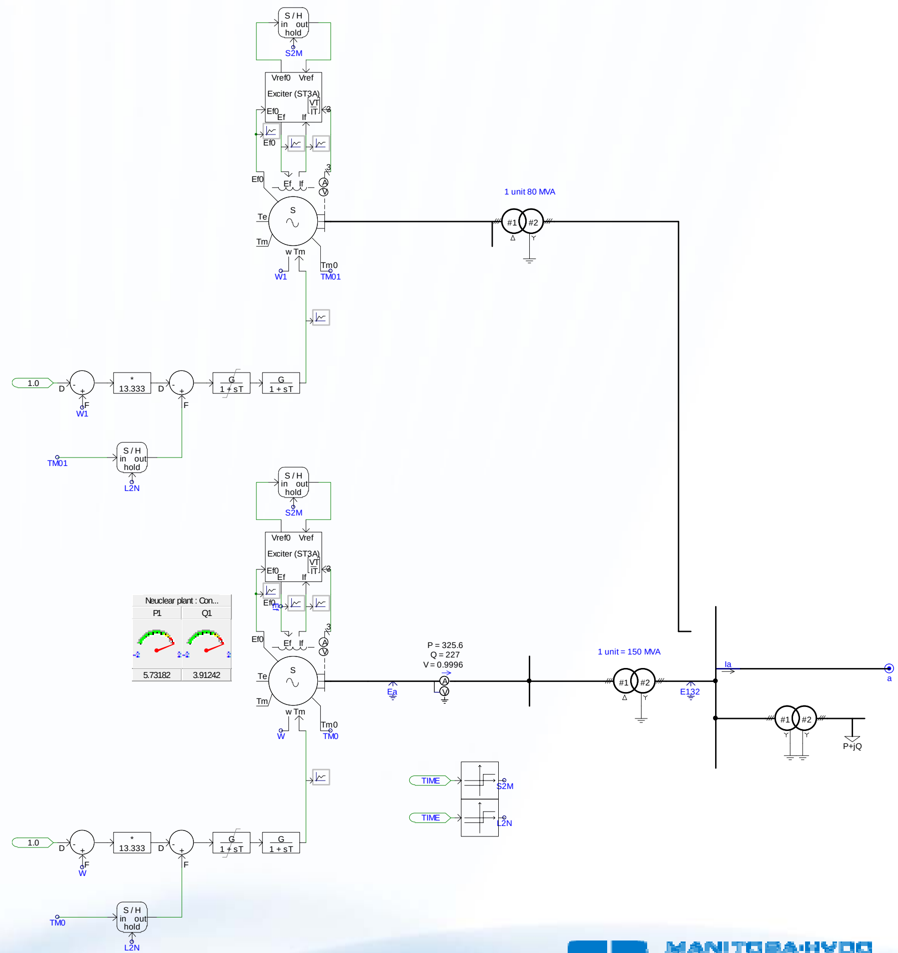
- Restoration steps are determined and documented – step by step

- System single line drawings are used to illustrate each step

- Electrical studies are necessary to verify that the selected restoration actions (steps) can be implemented without damaging equipment

System black start restoration studies

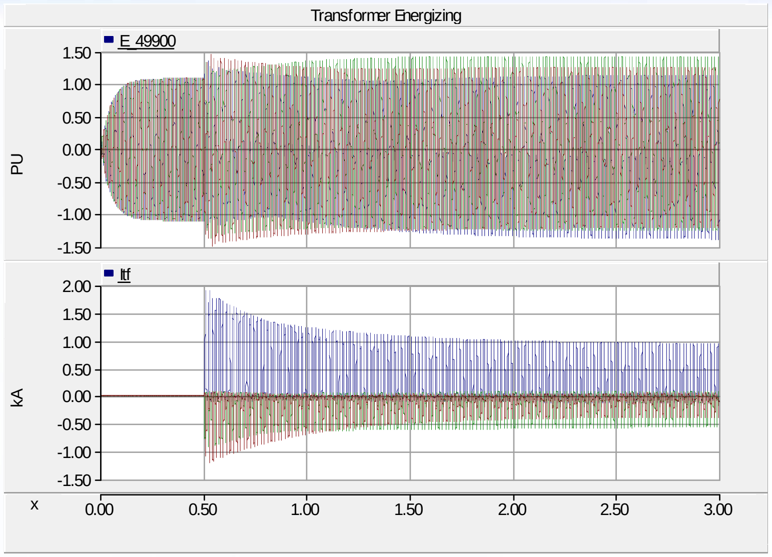


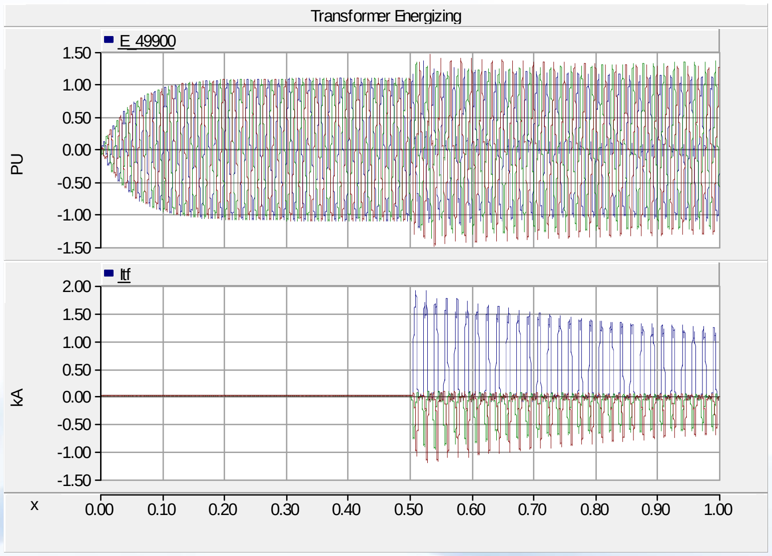


System black start restoration studies

Transformer energizing:

➢ Energizing a transformer from the HV side

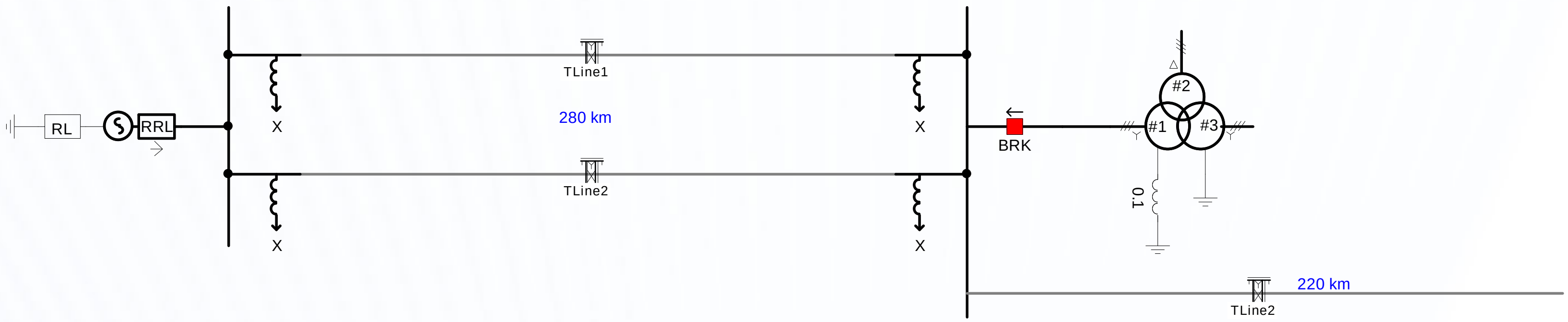


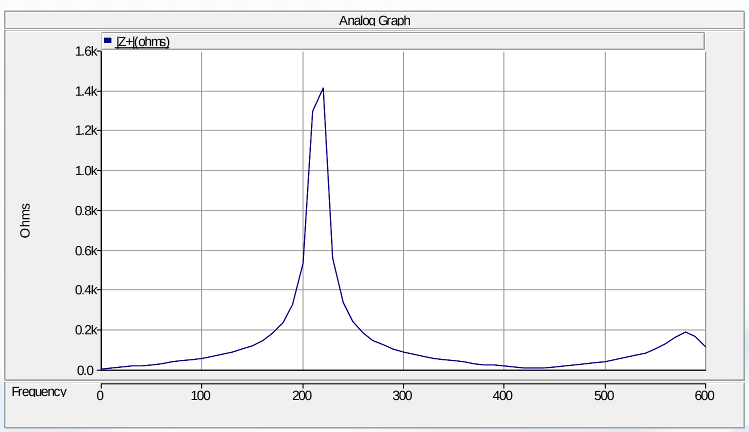


System black start restoration studies

Transformer energizing:

- Energizing a transformer from the HV side



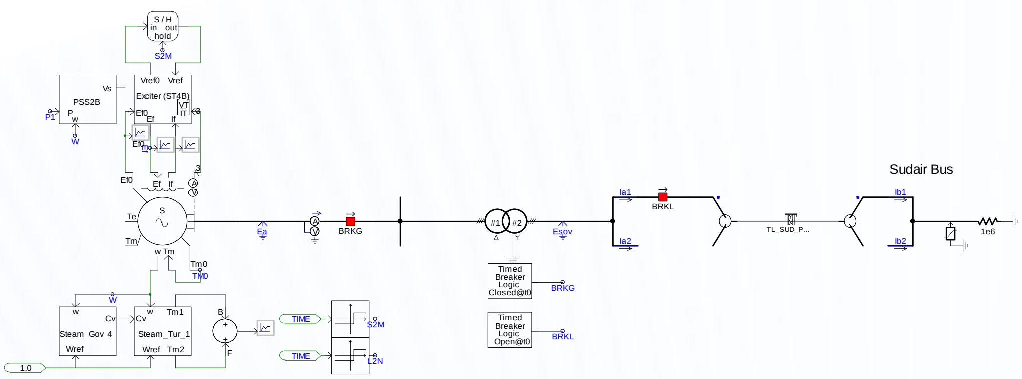


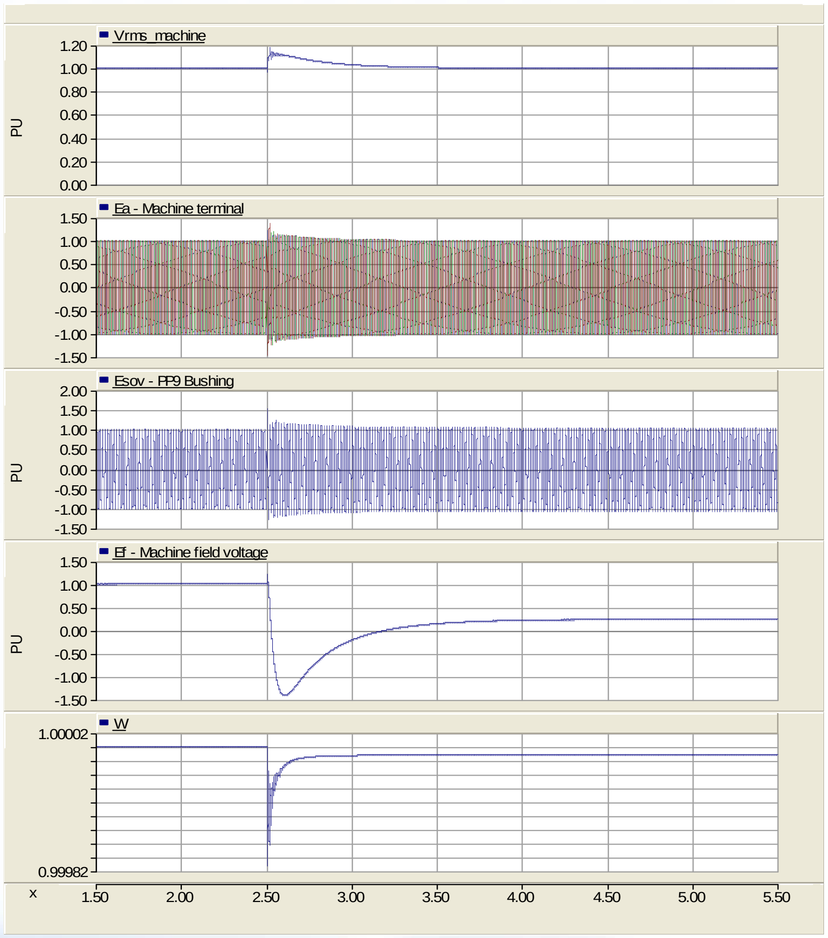
Manitoba HVDC *Research Centre*

System black start restoration studies

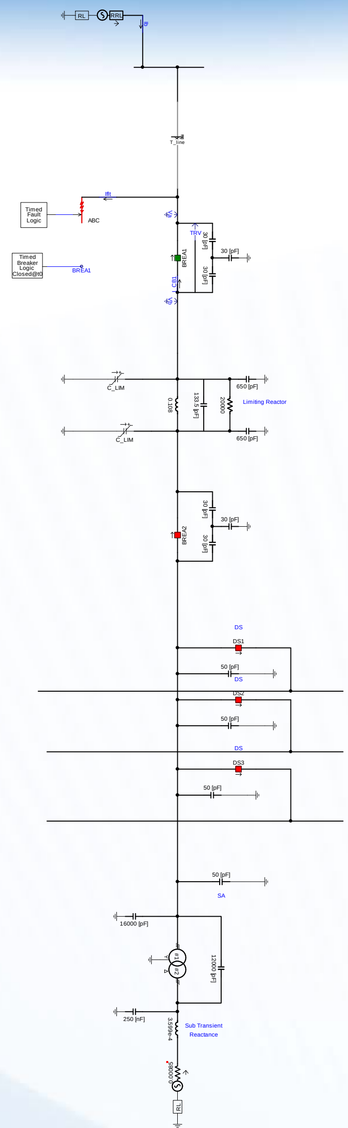
Long line energizing through small generating units

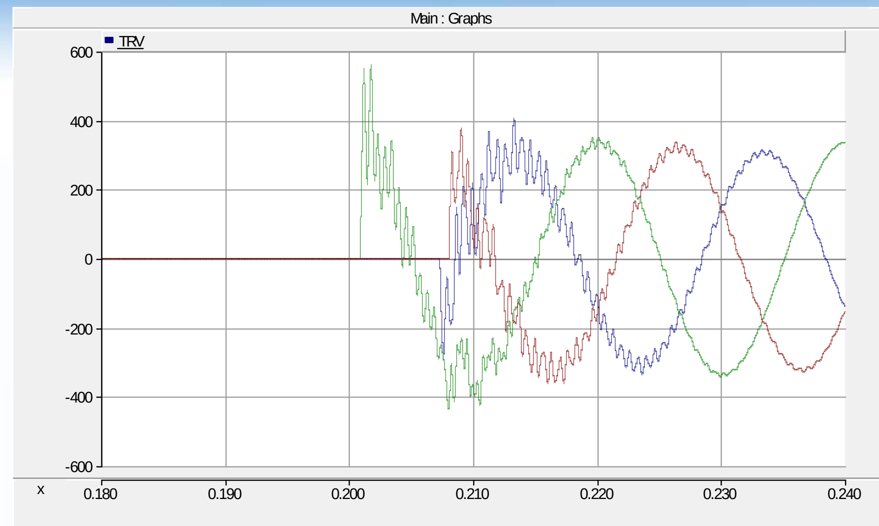
- ➢Self excitation issues

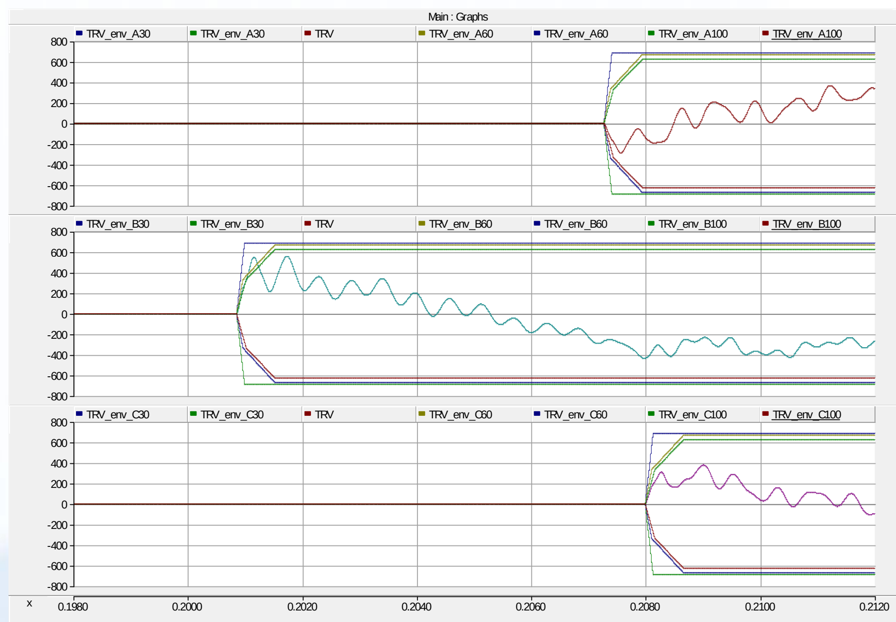




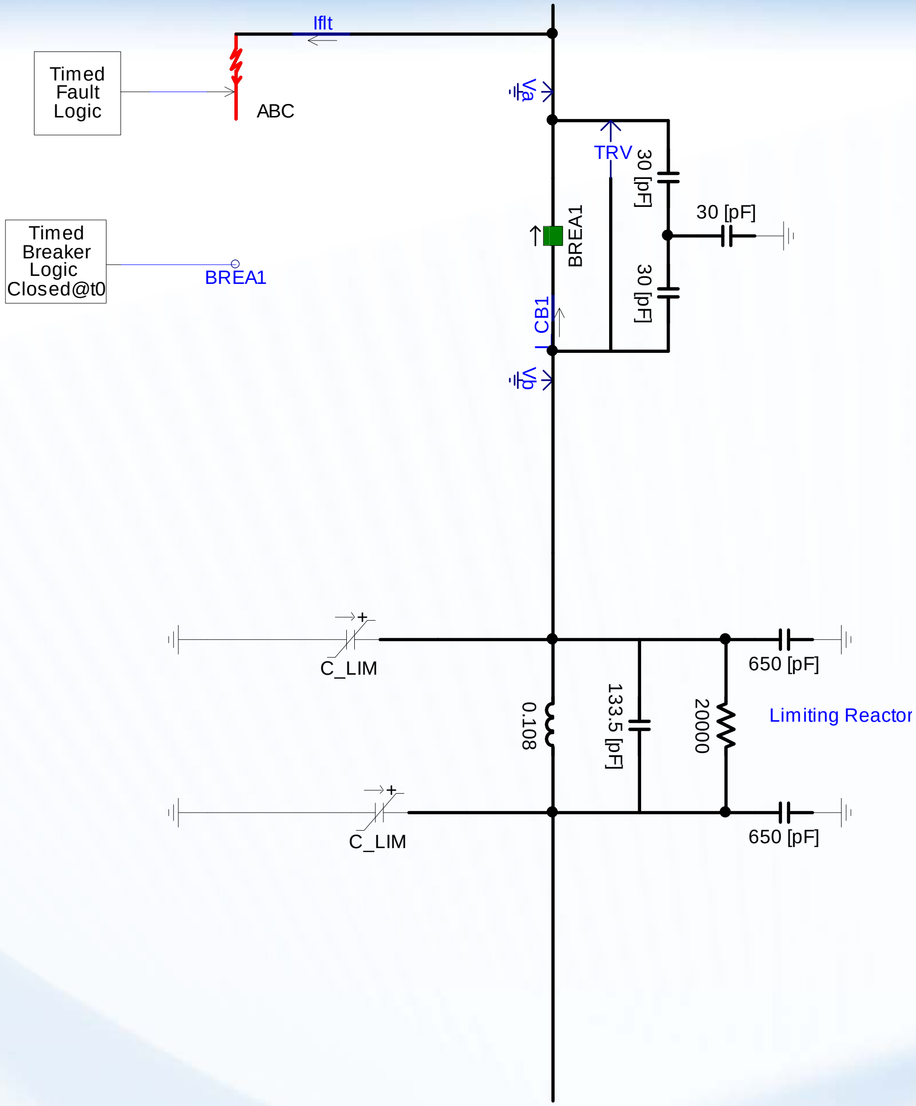
Breaker Transient Recovery Voltage - TRV

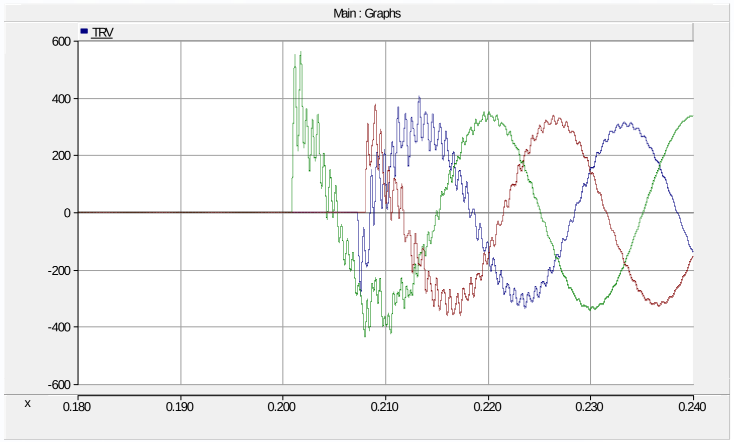






Breaker Transient Recovery Voltage - TRV



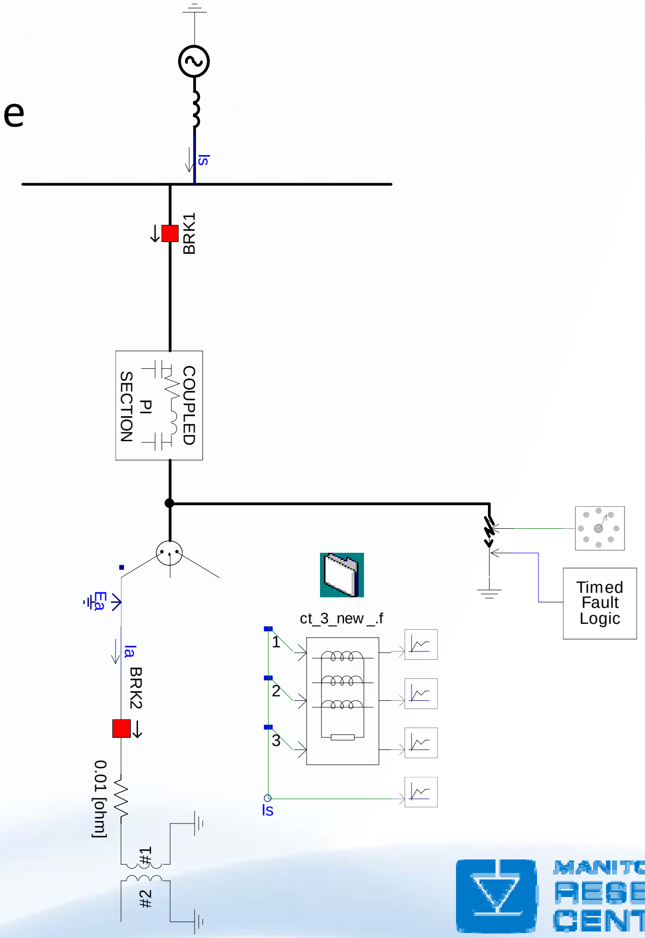


CT Saturation

Mal-operation of an earth fault relay during transformer energising.

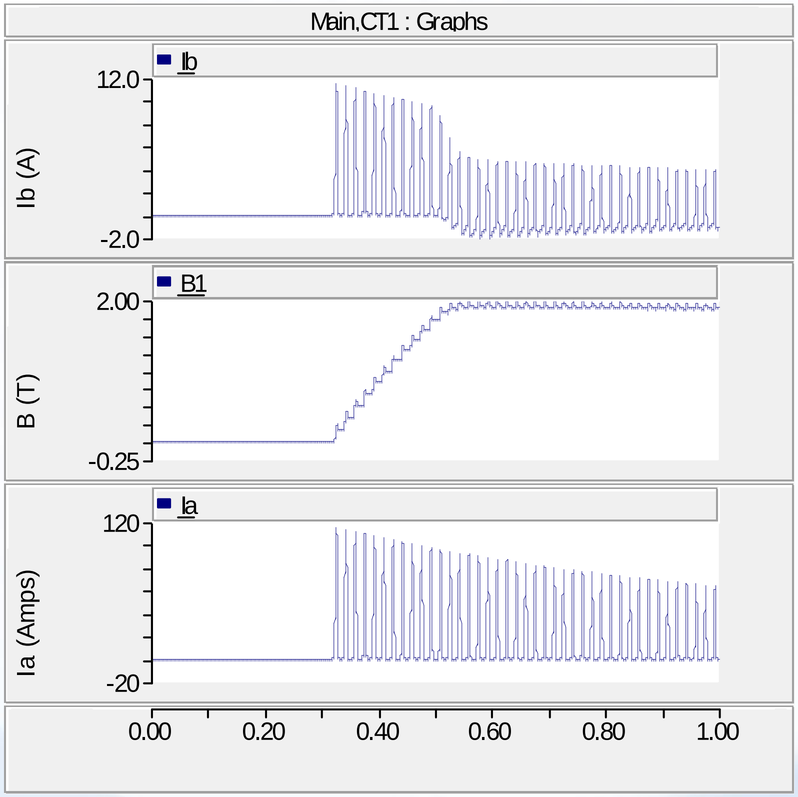
Inrush current caused unequal saturation of the 3 CTs, resulting in a ‘burden’ current.

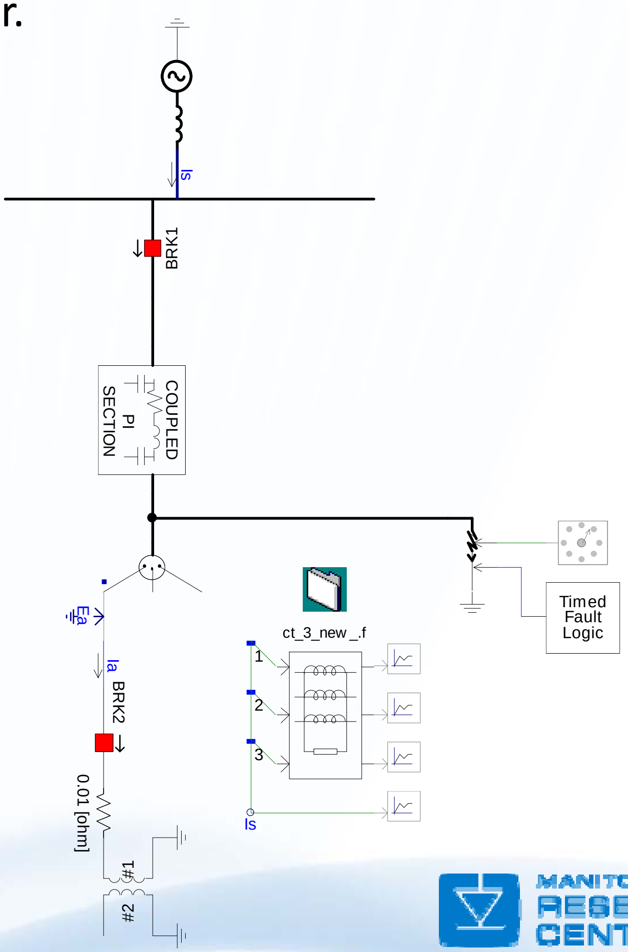
PSCAD case:
Earth_fault_relay.psc
(required ThreCt.psl and a custom Fortran file)



CT saturation studies

CT of phase A saturated during energising of a single phase transformer in a distribution feeder.





Open discussion and closing comments

Present your questions to PSCAD Developers and to your fellow PSCAD users.

Tell us of you PSCAD experience:

- How can we do better?