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2007 Summer Issue...

Announcing PSCAD® Version 4.2.1 Build 2007!

Mr. Paul Wilson, Managing Director, Manitoba HVDC Research Centre

The Manitoba HVDC Research Centre is pleased to announce the availability of a new build for the popular PSCAD® V4.2 software for power system electromagnetic transient simulation May 30th, 2007. This build of PSCAD® delivers to end-users important software maintenance revisions to ensure optimal operation of the software, particularly on new Microsoft operating systems. The most significant changes are: New installer support for XP 64, Vista, and Vista 64 operating systems. This build will also install on Windows 2000 and XP32 platforms. Installer supports signed Rainbow hardware lock drivers for 64 bit platforms.

An update of the License Manager (1.27) provides new support for: Windows XP 64 and Windows Vista, additional diagnostic messages, determination of the IP address of computers using VPN adapters.

Although PSCAD® has not changed with this release, some significant ancillary items include a new Spanish language online help file. Please see instructions online or in the readme.rtf file to activate. Users can access the help file within PSCAD® in the same manner. A new Master Library (V4.2.1.3) is provided with this build addressing a computation defect in four components. This library is also available on our PSCAD® website *www.pscad.com*

Available are new example cases for the IEEE 34 Bus system, a voltage regulator model, and an improved DFIG machine example. We are introducing a new PSCAD®/EMTDC™ Applications Guide with additional chapters on model verification, material on transformer modelling, and Real Time Playback.

For those users running V4.2.0, there are some significant items in the PSCAD® V4.2.1. The License Manager now handles the determination of the IP of computers with multiple Ethernet adapters which is particularly important for notebook computers with wireless adapters. See *http://bb.pscad.com* License Manager thread for further details on the multi-homed machine issue.

The behaviour of the slider/switch components has changed slightly when there is no associated control panel. Changes made to the default values (through parameter setting window) are not automatically applied. The initial value of the component when first created is always used. A right click control has been provided to immediately apply the value.

Support has been provided for Intel Visual Fortran V9.1 and beyond. The default library location for integrating with Fortran compilers has changed in Matlab. As a result, PSCAD® can no longer detect the library path when Matlab R2006a, 6b or 7a is used. There is a solution documented in the What's New section of the online help.

Users have been pleased with PSCAD®'s stability, performance, and features and this new build extends the accessibility of this popular product. We invite you to visit our PSCAD® Forum and the downloads section of our website *www.pscad.com*. Our customer support staff are also ready to help and your feedback, suggestions, and requirements are important to us. Please contact *support@pscad.com* if you have any questions or comments.

Tracing Ground Path Resonances in a Sub-transmission Network with Cables

Dr. Adel Hammad, SwissPowerSystems, Baden, Switzerland

This article summarizes a comprehensive study carried out by the Swiss Utility NOK following a 3-phase-ground fault at a 110kV cable terminal connected to a large distribution substation. The fault developed a particularly high overvoltage in another 110kV substation, which entailed damage to potential transformers and cable sheath arresters. The initial analysis showed that the overvoltage had a very high component at 127Hz.

This study was, therefore, necessary in order to clarify the source of this abnormal event and to define existing and future problems in the 110kV network and offer solutions to prevent potential problems encountered during the several phases of the 110kV network expansions.

The Fault Event Figure 1 depicts the part of the network affected during the disturbance. Most of the shown interconnections are cables. As shown in Figure 1, the 110kV network is fed from the 220kV transmission by Star-Star transformers with Delta tertiary windings. The neutral points on the 220kV side are solidly grounded, whereas most of the neutral points on the 110kV side are grounded through reactors to limit the zero-sequence short circuit currents. The 16kV distribution network is directly fed from the 110kV substations.

The disturbance course of events started by the inadvertent closing of the cable terminal grounding switch 'FT' while the breaker 'XB' at the other terminal 'B' is still closed. This developed a 3-phase-ground short circuit which was cleared by opening of the

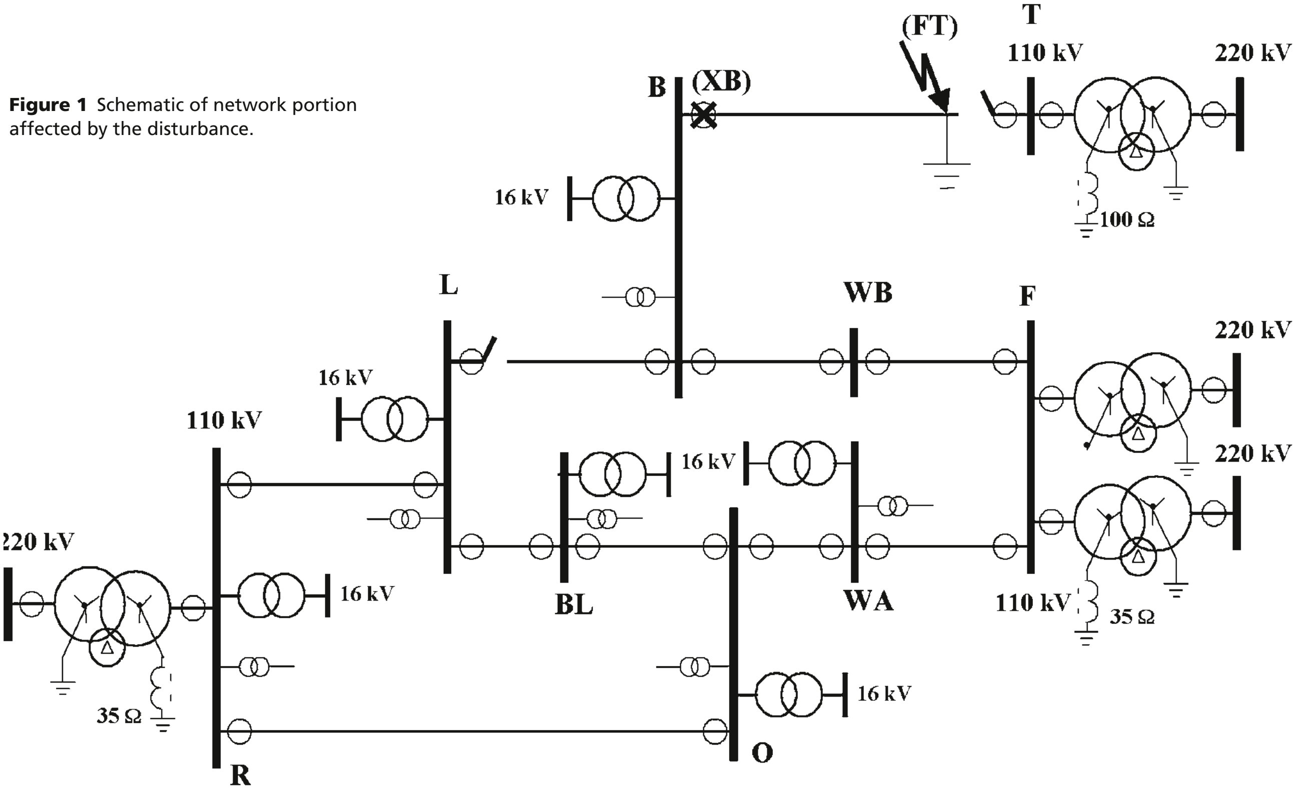


Figure 1 Schematic of network portion affected by the disturbance.

remote breaker 'XB' in about 400ms. Figure 2 shows the 3-phase voltage traces produced by the disturbance fault recorder located at substation 'WA'. However, after less than 20 seconds, several new phase-ground faults (phases c and a) occurred successively at substation 'WB' and on cables 'WB'-'B' and 'WB'-'F'. As a result, substation 'B' and all the 16kV distribution networks fed from it lost all supply. Apparently, the overvoltages that followed clearing the fault were of such high magnitude that caused damage to the voltage measurement transformers and cable sheath arresters in substation 'WB'. As shown in Figure 2, the voltage oscillates violently after the fault clearing with very high amplitudes and asymmetry between the phases. The oscillations and asymmetry are damped after approximately 250ms.

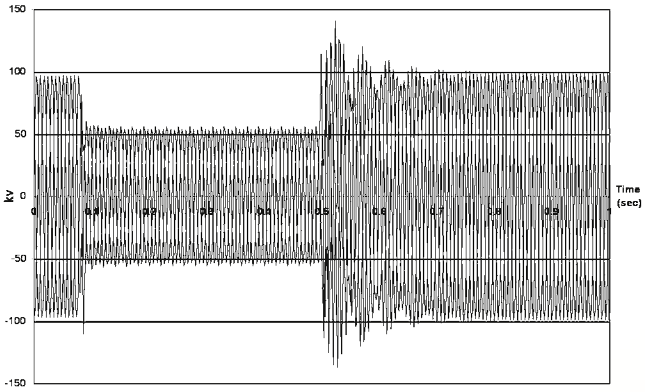
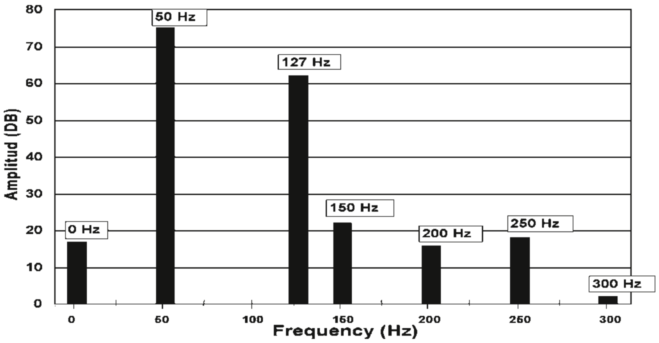


Figure 2 Three-phase voltage measured at substation 'WA' (1 second duration)

Figure 3 shows the Amplitude vs. Frequency of the measured voltage signal. Along with the 50Hz component and the DC offset one recognizes the very high component at 127Hz, followed by a smaller 150Hz component.

EMTDC™ Simulations The complete 110kV network of NOK was simulated in detail using PSCAD®/EMTDC™ simulations. The 16kV distribution networks connected to the substations in the vicinity of the disturbance were represented as well. Low order filtered measurements were also necessary to reproduce the actual measured signals. Minor adjustments of the 16kV load models were requisite in order to match the amplitude and damping of the measured voltage signals at substation 'WA'.

Figure 3 Frequency composition of the measured voltage.



Figures 4 and 5 depict respectively the voltage waveform at substation 'WB' and the filtered voltage at substation 'WA' of the EMTDC™ simulations. Although, in the actual disturbance, the fault lasted for about 400ms due to back-up relay operation, only 115ms fault was simulated to reduce the simulation execution time.

As shown in Figure 4, the voltage at 'WB' has very large spikes (particularly in phases c and a), at the fault clearing instant. The peak voltages at 'WB' are generally slightly higher than at 'WA'. Note that 'WB' has no 16kV feeders. Voltages at the other 110kV substations in the vicinity are similar to those at 'WB' and 'WA' with small differences.

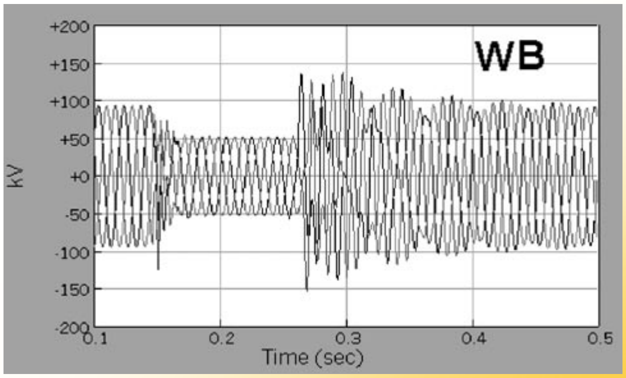


Figure 4 Simulated network voltage at substation 'WB'.

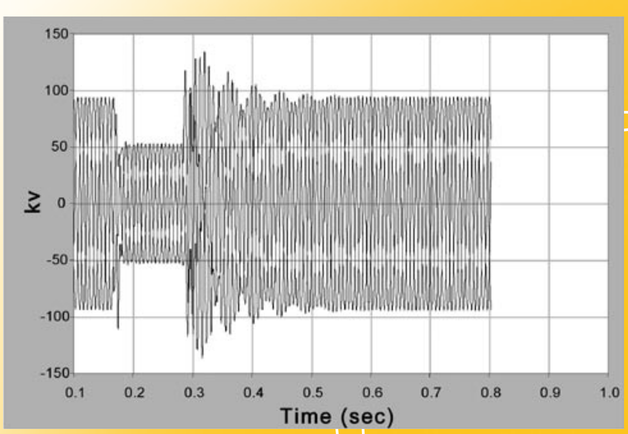


Figure 5 Simulated filtered voltage at substation 'WA'.

…the network, during fault commencement and fault clearing periods, is asymmetrical.

In order to make a meaningful comparison with the measured values, the simulated filtered voltage at 'WA' is split into two segments, namely at fault commencement and after fault clearing, and synchronized in time with the measured signal. The comparison of the 3-phases (a, b, c) of measured and simulated filtered voltage at 'WA' for the two segments is shown in Figures 6 and 7. Indeed, the similarity between the two signals is obvious and proves the accuracy of the model used for simulations.

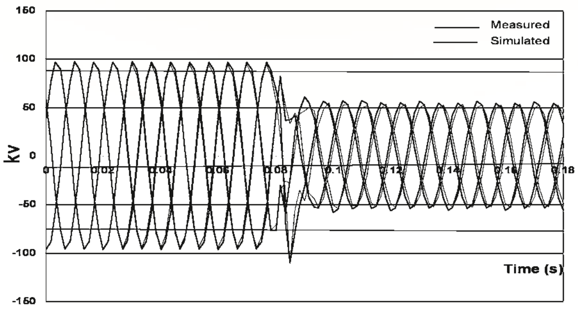


Figure 6 Comparison between measured and simulated filtered voltage at substation 'WA' at fault commencement.

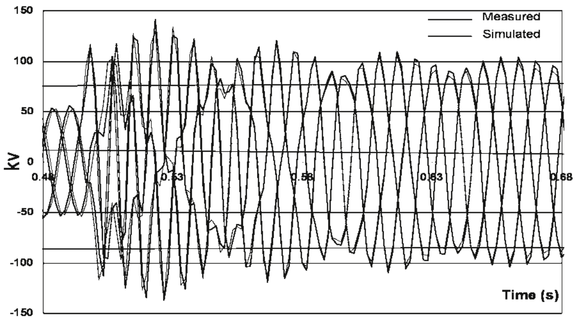


Figure 7 Comparison between measured and simulated filtered voltage at substation 'WA' after fault commencement.

Note that short-circuits in the three phases do not all commence simultaneously and the opening of the faulted line takes place for each individual phase successively. This means that the network during fault commencement and fault clearing periods is asymmetrical. Therefore, any frequency-domain analysis should consider all sequence impedances of the network. The frequency scan [1] for the sum of network positive, negative and zero sequence impedances seen at substation 'WB' is shown in Figure 8 during three stages of asymmetric operation of the network; (1) commencement of short circuit at 'FT' with resonance frequency of 100Hz, (2) opening breaker 'XB' with resonance at exactly 77Hz and (3) after clearing of the fault where the impedance resonance moves to 65Hz but has an additional peak at 77Hz. Due to the 50Hz carrier frequency effect of the AC system, a 77Hz resonance in the frequency domain shows as (77+50) 127Hz in the time domain. Similarly, the 100Hz resonance frequency shows as 150Hz in the time domain. The damping of such resonances is approximately inversely proportional to the peak impedance. It is clear that the 77Hz resonance is dominant, where as the 100Hz resonance is well damped. This result explains the outcome of frequency composition of the measured voltage of Figure 3.

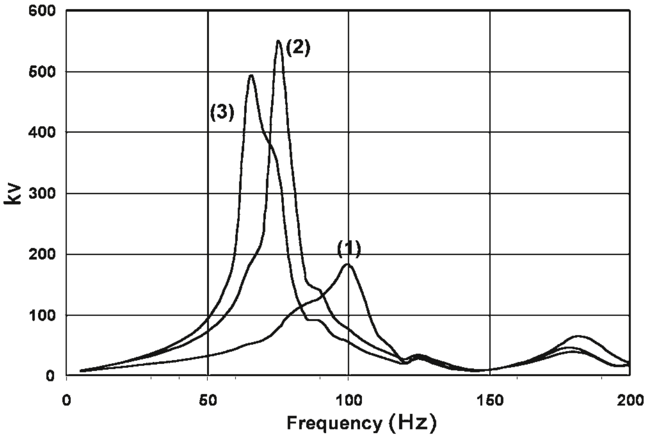


Figure 8 Frequency scan at substation 'WB' for asymmetric network operation: (1) during short circuit at 'FT', (2) during short circuit and opening of breaker 'XB', (3) after clearing of short circuit.

In an attempt to explain why the equipment damages were confined to substation 'WB' and to cables 'WB'-'B' and 'WB'-'F', the impedance frequency scan during short circuit and opening of breaker 'XB' is made for different sub-stations as shown in Figure 8. It is evident that the strongest resonance effect for this particular fault location lies at 'WB', 'B' and 'F' substations. A resonance that led to a very high overvoltages with 127Hz at those locations.

Editors' Note: It is our understanding that the frequency domain analysis is performed to capture resonant variations in fundamental frequency signals (i.e. similar to amplitude modulation).
This translates to resonant frequencies f0-f and f0+f in real signals.

Reducing the reactance of neutral-point grounding reactors can be a possible solution for alleviating the low frequency resonance problem…

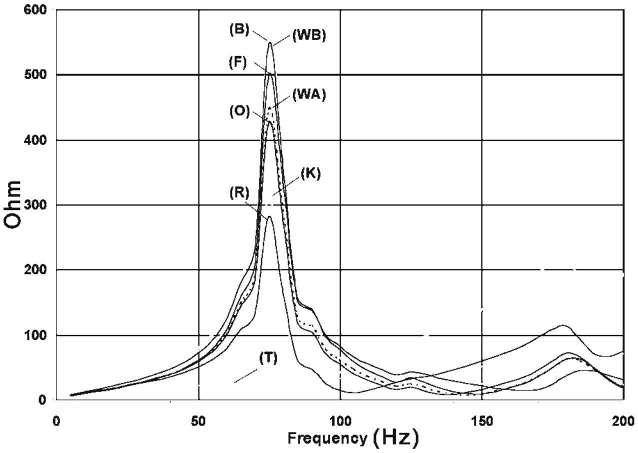


Figure 9 Frequency scan at different substations for asymmetric network operation during short circuit and opening of breaker 'XB'.

Resonance influencing factors:

Fault Type Both 3-phase-ground and 2-phase-ground faults can excite such low frequency resonances that can cause dangerous overvoltages.

Circuit Cable Content Due to the difficulty of isolating all the factors affecting the resonance and the arising overvoltages, a range of 25% to 30% of cable content was identified as being a critical limit regarding this phenomenon.

Neutral Point Grounding Since the resonance is predominantly affected by the zero-sequence impedance of the network, the relatively high values of neutral-point grounding reactors used throughout the network are the main cause of the low frequency (< 200Hz) resonance problem.

Damping of Resonance Reducing the reactance of neutral-point grounding reactors can be a possible solution for alleviating the low frequency resonance problem [2]. However, the obvious disadvantage of this method is the increase in fault currents that may be beyond the existing switchgear design values.

Another method for mitigating or completely eliminating the network resonance and its consequent high overvoltages is by increasing the resonance damping, without changing its frequency of oscillations. This can be realized by adding a small resistance in series with the existing neutral point reactors or, equivalently, by adding a large resistance in parallel to those reactors. In order to demonstrate the effectiveness of this solution, the same fault case is simulated but with all neutral point grounding reactors shown in figure 1 fitted with parallel resistors having approximately 3 x the impedance value of such reactors. For this case, Figure 10 is presented to show the 3-phase voltage at 'WB'. Note how the overvoltage is reduced and all post-fault oscillations are practically eliminated.

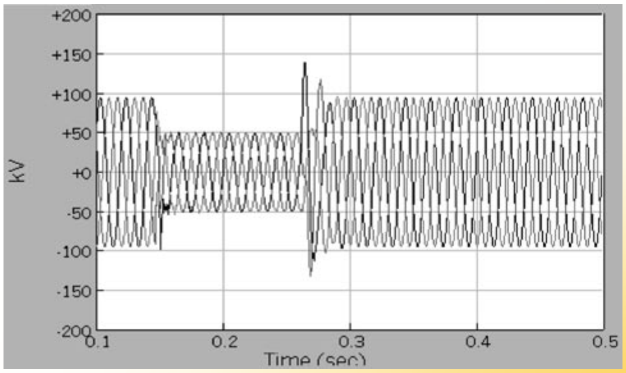


Figure 10 Voltage at substation 'WB' with parallel neutral point resistances.

For practical implementation of a standard economic solution, all existing and future neutral point reactors in the network are replaced with new reactors having very high inherent resistance by using different material other than aluminium.

References

[1] A. Hammad, 1990, "Eigenvalue and Frequency Domain Analysis of Second Harmonic Resonance in a Complex AC/DC Network", *IEEE Power Engineering Society Special Publication*, No. 90, TH0292-3 PWR, 61-66.

[2] S. Läderach and G. Köppl, 2001, "Beeinflussungs-problem bei Mehrfachleitungen", *Bulletin SEV*, 7/02, 9-12.

Field Verification of the Conductor Icing Detection System

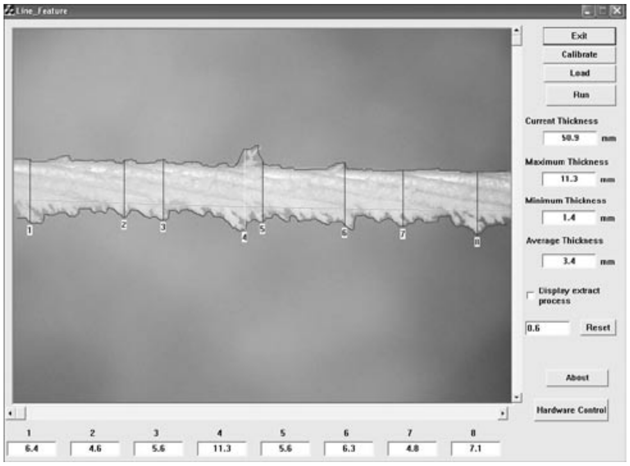
Mr. Pei Wang and Mr. Norm Tarko, Manitoba HVDC Research Centre
Mr. Monty Peckover, Manitoba Hydro

Manitoba Hydro overhead transmission and distribution systems are prone to icing conditions due to adverse weather conditions. To reduce potential icing damage requires fast and accurate ice detection, and prompt ice removal process. A new ice detection system based on advanced vision recognition technology has been in development at Manitoba HVDC Research Centre. Phase I work focusing on proof-of-concept and lab verification was published in the Pulse Journal Spring 2006. Field verification of the conductor ice detection system is covered here.

Field Deployment Two prototypes of the ice detection system suitable for harsh outdoor environment operations have been developed in Phase II work. During the winter of 2005/06, the 1st prototype system was installed at the Manitoba HVDC Research Centre outdoor test line for overall system performance testing. In December 2006, the 2nd detection system as shown in Fig. 1 was commissioned by Manitoba Hydro staff on a 66kV line near a substation which is prone to the icing conditions based on historical ice data. The system communicates with its server program located at a substation through a wireless link for data access. The wireless link is approximately 500m from this site, but can reach 10km within line-of-sight.

Reliable Field Results Field data collected in the last two-winter trial periods prove reliable performance of this new conductor ice detection system. All conductor icing events that have occurred to date at the test site were successfully detected and alarmed. Icing conditions observed were caused by hoar frost, clear ice or ice frazil, and some sample icing data from the sites are shown in Fig. 2 to 5.

Figure 1 Ice system set-up on 66kv line



Current Thickness 50.9 mm
Maximum Thickness 11.3 mm
Minimum Thickness 1.4 mm
Average Thickness 3.4 mm
☐ Display extract process
0.6

1	2	3	4	5	6	7	8
6.4	4.6	5.6	11.3	5.6	6.3	4.8	7.1

Figure 2 Hoar frost inception on conductor

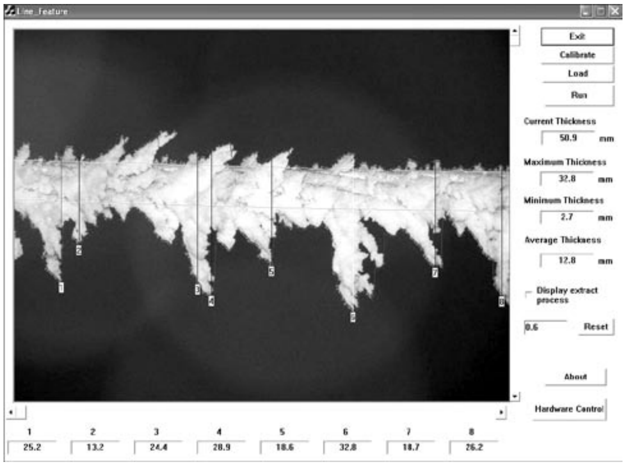
…accurately measure ice profiles directly on conductors with a non-intrusive technology in real time.

System Feature The Manitoba Hydro field installation will remain in-service through 2007, and critical elements of the conductor ice vision detection have now been verified, including:

- Accurate measurement of ice profiles directly on conductors in an automatic mode and real time (7/24).
- Collections of temperature and ice weight information
- Wireless communication for remote access and control
- Secured system integration with power utility network for on-line monitoring (ice data review, real time picture capture and downloading)
- Detection of transformation of hoar frost to ice (ongoing and pending on proper ice forming conditions)

Benefits Provided The conductor ice detection system can accurately measure ice profiles directly on conductors with a non-intrusive technology in real time. Once fully deployed, monitoring staff can establish priorities ensuring appropriate and consistent dispatch of resources. It will also provide means to set up an ice accretion database, and information on shapes and sizes of ice accretions can be used to improve the design of future power lines. In addition, as the type and size of ice may affect the amount of current required during ice melting, actual pictures of the ice accretions gives engineering staff more information to optimize the ice melting currents, therefore improve its process.

Future Work Planning of a large scale system deployment is in the process. Additional efforts are also underway to reduce the system size and cost, and enhanced graphical user interface to facilitate the operation of multiple conductor ice detection systems.



Current Thickness 50.9 mm
Maximum Thickness 32.8 mm
Minimum Thickness 2.7 mm
Average Thickness 12.8 mm
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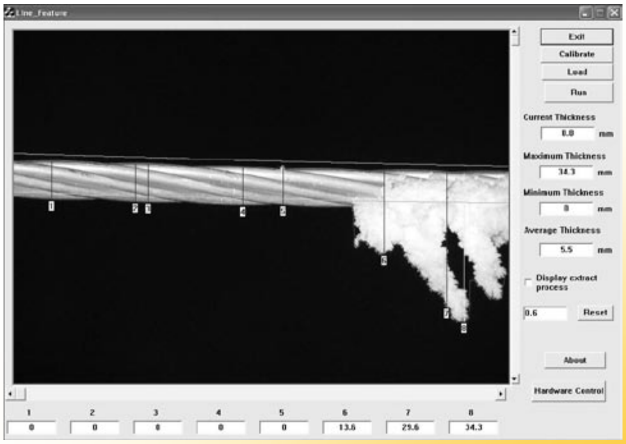
1	2	3	4	5	6	7	8
25.2	13.2	24.4	28.9	18.6	32.8	18.7	26.2

Figure 3 Hoar frost accumulation on conductor



Current Thickness 0.0 mm
Maximum Thickness 34.3 mm
Minimum Thickness 0 mm
Average Thickness 5.5 mm
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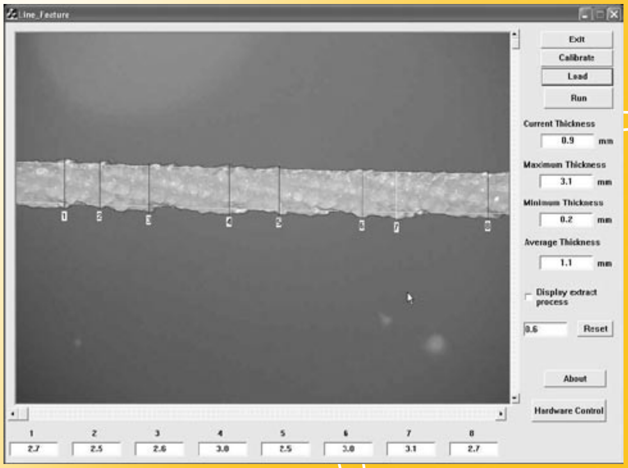
1	2	3	4	5	6	7	8
0	0	0	0	0	13.6	29.6	34.3

Figure 4 Hoar frost melting on conductor



Current Thickness 0.9 mm
Maximum Thickness 3.1 mm
Minimum Thickness 0.2 mm
Average Thickness 1.1 mm
☐ Display extract process
0.6

1	2	3	4	5	6	7	8
2.7	2.5	2.6	3.0	2.5	3.0	3.1	2.7

Figure 5 Clear ice detected on conductor

Large Scale EMT Studies – PSCAD® and E-TRAN

Garth Irwin, Dennis Woodford, Andrew Isaacs – Electranix Corporation

Study Requirements Electro-magnetic transients (EMT) studies require a circuit representation which is able to accurately reproduce the overall system frequency response (i.e. the harmonic impedance) to achieve the correct transient response. Some studies also require a reasonably accurate representation of electro-mechanical effects (i.e. generators, motors, governors, exciters…). These studies include sub-synchronous resonance (SSR) studies, series capacitors studies, HVDC and SVC interaction studies and transient over-voltage (TOV) studies with lines using fast-reclosing. To meet these study requirements, this article discusses the methodology we follow to build transient models using PSCAD® and the E-TRAN program.

Methodology The study methodology followed to create a PSCAD® model that includes both the correct frequency response and the correct mechanical response is as follows:

1) Start with a solved loadflow case. E-TRAN accepts raw input files (all recent versions) and will translate this data into PSCAD®.
2) Determine how big of an electrical and mechanical system has to be included in the model by E-TRAN translation of successively larger systems. The harmonic impedance is computed (using the PSCAD® harmonic impedance Z(f) component) and the size of system translated should be increased until the harmonic impedance no longer changes appreciably in the transient frequency range of interest (typically 0 to 2 kHz).
3) Develop detailed models of nearby devices that can affect results (HVDC ties, SVCs with custom controls, T-Lines with detailed line geometries, etc) and store them in a PSCAD® library. Detailed models are stored in the library/database according to the loadflow "from" bus, "to" bus and the circuit number – this allows E-TRAN to initialize (see below) and to use the detailed models in the PSCAD® case.

The library/database is the key piece of data that needs to be backed-up and saved – eventually the library will increase in size until detailed models for the full system has been entered and a study model can be quickly generated for anywhere in the system.

4) Translate a case into PSCAD® using E-TRAN:
   a. The circuit is auto-routed into PSCAD® single line diagram (SLD) format.
   b. A multi-port system equivalent is auto-created for the portion of the network not represented in PSCAD®.
   c. Machines, exciters, governors, stabilizers, min/max excitation limiters and compounding models are directly translated from the transient stability .dyr file into PSCAD® – all standard models have been written in PSCAD® and tested. This process also fully initializes the machines and controls so they start at the correct loadflow.
   d. If detailed models are found in the library/database, they will be initialized and used to create the PSCAD® .psc case – otherwise models will be created based on the loadflow data. Transmission line data from the loadflow is represented as a Bergeron model (if the line travel time is longer than the time step) or as a PI section (for short lines).

Size of System to be Modelled The harmonic impedance of the system is dominated by the overall system strength (i.e. the inductance), and the location of shunt capacitor banks and the capacitance of long transmission lines. Generators, which have a frequency response similar to the sub-transient reactance to ground, have a general impact of masking the system beyond (as anything beyond is in parallel with this small inductance). The harmonic impedance has been observed to change for systems going up to 10 busses away from the study point. Successively larger systems are translated into PSCAD® until the harmonic impedance as seen from the study point no longer changes.

Once enough of the system is translated to get a reasonable frequency response, the busses of dominant machines, DC links and SVCs (which are outside of the area translated thus far) are added to the list of busses. Non-critical low voltage busses can often be removed to reduce the size of the PSCAD® model (unless they have large loads connected whose dynamics are important to the study). The system kept in the PSCAD® model does not have to be continuous – for example you could translate all machine busses only (including dynamic models and controls) and E-TRAN would compute an equivalent impedance network linking all the machines. The shaded area in Figure 1 is the network E-TRAN translates into a PSCAD® Single Line Diagram. The remainder is modelled as a multi-port network equivalent.

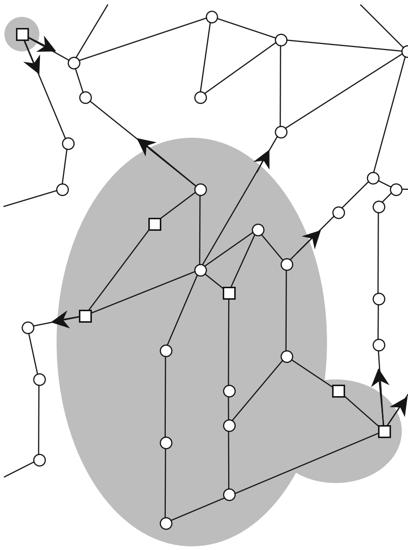


Figure 1 Original 40,000 bus loadflow.

E-TRAN will then translate the system contained within the list of selected busses into PSCAD® and will create a fundamental frequency multi-port network equivalent for the remainder of the system. The network equivalent contains diagonals (with voltage sources behind impedance) and off-diagonal impedances (i.e. the coupling between the busses which "border" the kept network) – this is computed with a precise and direct LDU matrix reduction method. This method is accurate for steady state, open circuit and short-circuits anywhere in the network. A fundamental frequency equivalent is applicable because enough of the circuit has been represented to ensure a good harmonic impedance representation as seen from the study focal point. Figure 2 shows the final PSCAD® model – the network equivalent is inside the sub-page.

The large arrows in Figure 2 indicate the location of boundary busses where the PSCAD® circuit interfaces to the network equivalent.

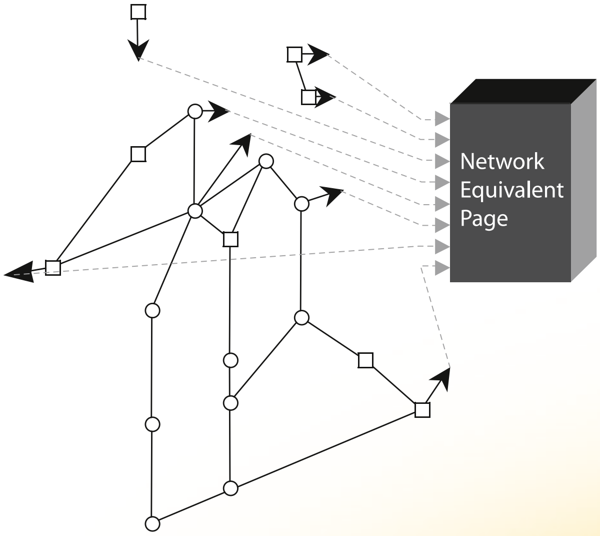


Figure 2 PSCAD® model (1,000 bus, 8 nearby generators).

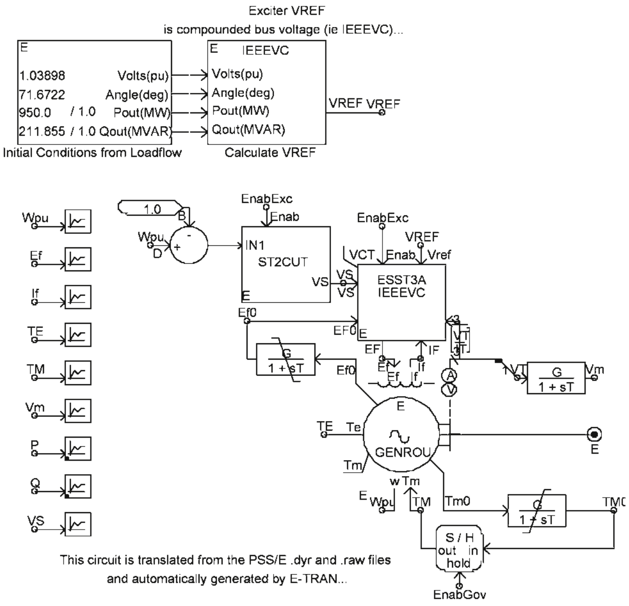
Dynamic loads are modelled in the simulation model as per the loadflow (i.e. constant PQ, constant current or constant impedance), so loads in the study area should be converted prior to translation into PSCAD® The load characteristics can be critical, particularly to reproduce voltage collapse conditions and transient recovery from faults.

Detailed Models – Database and Initialization

Detailed models are kept in a PSCAD® library/database for the entire system. These models can include frequency dependent transmission lines, shunt capacitors (with inrush reactors or inductance of tuned filters), HVDC/SVC models, transformers with wye-delta windings and saturation, plots, controls as well as templates for faults, protection sequences, multiple runs, SSR/torsional studies.

The models in the library/database are initialized by E-TRAN prior to generating the PSCAD® case – this is necessary to precisely match the system loadflow and to avoid large startup times in the PSCAD® simulation. The initialization process includes transferring of the following parameters from the loadflow into detailed PSCAD® models:

- Transformer tap settings
- Number of switched shunt capacitors or reactors in service
- Generators and control initialization (V, Angle, P and Q, correction of 30 degree delta windings)
- HVDC links (converter transformer tap settings, power order, power direction, number of switched reactive filters in service)
- SVCs (voltage set-point, reactive power and switched shunts)
- In service status of devices (i.e. disabling of devices for contingency conditions)



This circuit is translated from the PSS/E .dyr and .raw files and automatically generated by E-TRAN...

Figure 3 Machine model translated from PSS/E .dyr into PSCAD®

The power flow in the final PSCAD® case will match the loadflow to about 3 or 4 decimal points of accuracy everywhere in the system, providing the steady state impedances of models in the detailed library match the data in the original loadflow. This is achieved with a PSCAD® startup simulation time of 0.2 seconds (for AC only cases) or typically 0.5 to 1.0 seconds for cases with HVDC links (the time to steady state depends on how long the HVDC model takes to reach steady state). Machines are then initialized and released without bumps or transients.

Challenges Translation of models from Transient Stability (TS) data can pose some challenges:

- Transient stability models for exciters can use large proportional gains without smoothing of the measured voltage – there is an inherent 1 cycle smoothing in rms voltage calculations in EMT programs, which may cause a different response.
- Exciter and stabilizer models from TS data are based on the machine primary mechanical swing frequency (1-2 Hz) and are often not valid at torsional/SSR frequencies or at higher transient frequencies. EMT models can include higher frequency transients (due to torsional response, negative sequence quantities reflected to 2nd harmonic quantities, or harmonic distortion from switching models) which can also be impacted by simplified exciter or control models.
- Off-diagonal elements in the system equivalent (generated by E-TRAN) are represented by RL branches (if the voltages are the same) or by ideal transformers (if they are different) – the inclusion of resistance in an ideal transformer in PSCAD® V4.2 adds 6 additional nodes for a 3 phase transformer, which greatly increases the overall # of nodes required in the simulation. A new ideal inverter RL matrix transformer data entry has been developed by the Centre which will resolve this concern in future PSCAD® releases.

Example Cases:

Basslink HVDC Studies – A model of the complete island of Tasmania was developed in PSCAD® and can be translated for any loadflow case. A detailed HVDC model (from the manufacturer) is included in the library. The size of system translated was approximately 300 busses (the complete island so system equivalents were not used) and included

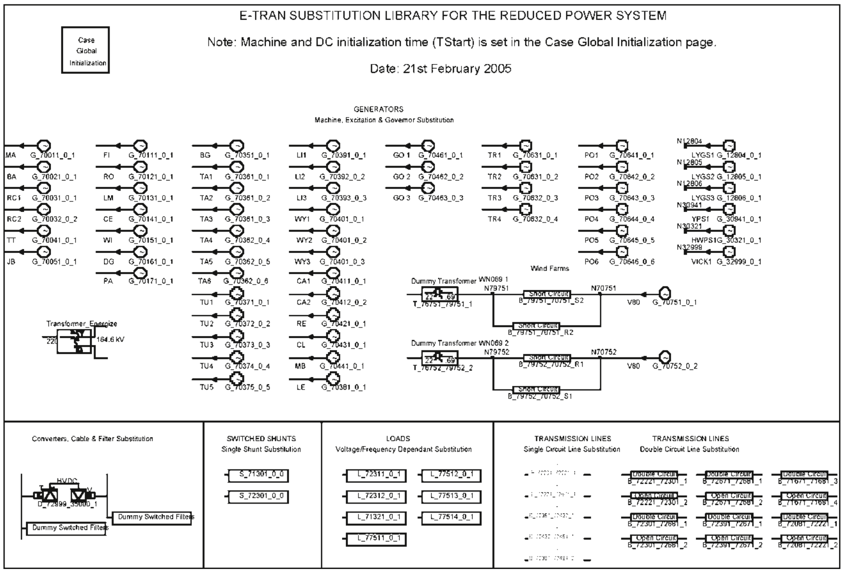


Figure 4 Library of detailed models.

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60+ generators (with custom governor and exciter models). Large system models were required to reproduce the overall system frequency and special protection systems (i.e. over/under frequency load/generation shedding caused by emergency tripping of the HVDC converter). Comparisons of the PSCAD®/E-TRAN model were made to the real system response for transient tests during the commissioning of the HVDC converter with excellent comparisons.

Namibia HVDC Studies – A model of all of Namibia was developed in PSCAD® and can be translated for any loadflow case. Four different HVDC models were developed in the library (different configuration options being considered). The size of system translated was more than 200 busses (all of Namibia and extending North and South) and included 20+ generators (with custom governor and exciter models). Large system models were required to reproduce the overall system frequency, weak system interactions and machine transient stability after recovery from faults.

Series Capacitor Studies – Recently three different series capacitor studies were performed which required large scale simulation models. Study methods included a screening analysis based on harmonic impedances and impedance dips, followed by time domain perturbation analysis to determine net electrical torsional data, as well as large signal fault analysis using multi-mass models.

- Study 1: Over 175 busses, 20+ generators (and 25 custom exciter/governor models) and models for 5 nearby SVCs.
- Study 2: Over 300 busses, 35+ generators, 1 SVC and an HVDC link.
- Study 3: Over 200 busses, 25+ generators, 1 SVC and an HVDC link.

Simulation times for these systems are remarkable considering they are 3 phase, unbalanced, non-linear EMT models – possibly the largest EMT models in the world using thousands of nodes. An example case (>2500 nodes, 28 generators with detailed exciters, governors, stabilizers, an SVC and an HVDC link) took 26 minutes for a 1 second simulation. The case was initialized and in steady state by 0.5 seconds with all machines released without bumps or disturbances.

Summary Large-scale PSCAD® studies are able to reproduce the harmonic impedance frequency response of the system and include numerous machine and control models to reproduce dominant machine oscillations and responses. E-TRAN is able to directly translate loadflow and transient stability machine and control models into PSCAD® (including the formation of system equivalents) and initialize detailed PSCAD® models for a clean start-up which precisely matches the loadflow in the entire system. A significant investment has been made in these studies to develop a PSCAD® library of detailed models that may be easily re-used in future studies for any loadflow case using E-TRAN and PSCAD®.

Please contact *gdi@electranix.com* if more information is required on E-TRAN or these study techniques.

Expanding Knowledge

The following courses are available, as well as custom training courses - contact *sales@pscad.com* for more information.

Introduction to PSCAD® and Applications
Includes discussion of AC transients, fault and protection, transformer saturation, wind energy, FACTS, distributed generation, and power quality with practical examples. *Duration: 3 Days*

Advanced Topics in PSCAD® Simulation Training
Includes custom component design, analysis of specific simulation models, HVDC/FACTS, distributed generation, machines, power quality, etc.
Duration: 2–4 Days

HVDC Theory & Controls
Fundamentals of HVDC Technology and applications including controls, modelling and advanced topics. *Duration: 4–5 Days*

AC Switching Study Applications in PSCAD®
Fundamentals of switching transients, modelling issues of power system equipment, stray capacitances/inductances, surge arrester energy requirements, batch mode processing and relevant standards, direct conversion of PSS/E files to PSCAD®. *Duration: 2–3 Days*

Machine Modelling including SRR Investigation and Applications
Includes machine equations, exciters, governors, initialization of the machine and its controls to a specific load flow, typical applications, SSR studies with series compensated lines as the base case. *Duration: 2 Days*

Distributed Generation & Power Quality
Includes wind energy system modelling, integration to the grid, power quality issues, and other DG methods such as solar PV, small diesel plants, fuel cells. *Duration: 3 Days*

Wind Park Modelling
Includes wind models, aero-dynamic models, machines, soft starting and doubly fed connections, crowbar protection, low voltage ride through capability. *Duration: 3 Days*

Industrial Systems Simulation & Modelling
Includes motor starting, power quality, capacitor bank switching, harmonics, power electronic converters, arc furnace, protection issues.
Duration: 1–2 Days

Lightning Coordination & Fast Front Studies
Substation modelling for a fast front study, representing station equipment, stray capacitances, relevant standards, transmission tower model for flash-over studies, surge arrester representation and data. *Duration: 2 Days*

Modelling and Application of FACTS Devices
Fundamentals of solid-state FACTS systems. System modelling, control system modelling, converter modelling, and system impact studies.
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