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Application of Superconducting Fault Current Limiter in HVDC Systems

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Over recent years, HVDC transmission is recognized as a viable means of transmitting power over long distances. In the case where AC transmission is difficult from an environmental, technical and economical point of view, BTB-HVDC and VSC-HVDC systems offer environmentally friendly solutions. These HVDC networks are much more significant in the context of liberalization of the electrical market. Further, interconnections of the DC network, as in AC systems, will definitively improve the system operation and reliability. However, these networks suffer from the disadvantages that there is no zero crossing of the DC fault current, which makes circuit interruptions difficult. This problem is presently overcome with sophisticated controllers for the power converters. A superconducting fault current limiter (SCFCL) can be a technically and economically attractive alternative, especially in the case of isolated grid supply for offshore applications.

SCFCL provides ultra-fast transition from super conducting to normal state during fault conditions and is self-operating and repetitive in nature. A number of studies concerning types of SCFCLs, material aspects, prototypes and testing have been suggested in the literature [1]-[5]. However, their application in power systems and in particular for HVDC systems, has received very limited attention.

In this context, it is of interest to study the application of resistive SCFCL in an HVDC system.

The dynamic analysis of an HVDC system, including the resistive SCFCL, would require a detailed understanding of the resistive SCFCL. The nonlinear *E-J* characteristic, exhibited by all HTS materials is shown in Figure 1, which exhibits a very strong dependence on temperature.

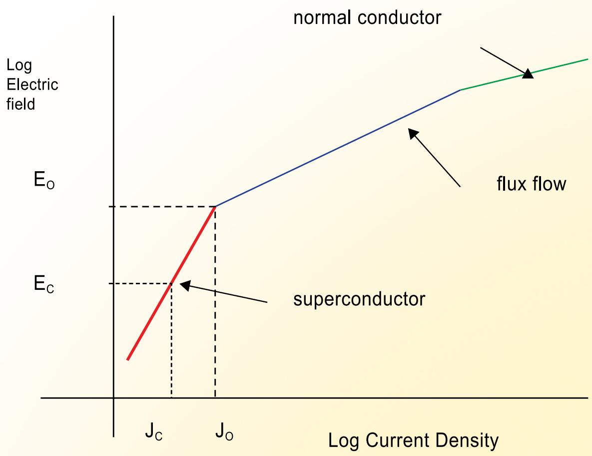

Figure 1 E-J characteristic of HTS material

Accordingly, the present work aims to discuss the modelling and simulation details of SCFCL. The model of resistive SCFCL based on E-J characteristics is modelled in MATLAB and then interfaced with the dynamic model of HVDC systems (CSC-HVDC and VSC-HVDC) simulated in PSCAD™/EMTDC™ environment. Figures 2 and 3 shows the two terminal CSC-HVDC and VSC-HVDC systems, respectively. The SCFCL is interfaced on the DC side of a rectifier.

The dynamic analysis of the system is then carried out for different fault conditions to understand the behaviour of SCFCL and its effect on the dynamic performance of the HVDC systems. Figure 4 (a, b, c) shows the performance of the CSC-HVDC system with SCFCL for single phase to ground fault. Here with SCFCL, the DC current is clipped from 1.65 pu to 1.45 pu. This result indicates that the SCFCL is very effective in reducing the fault current within half a cycle.

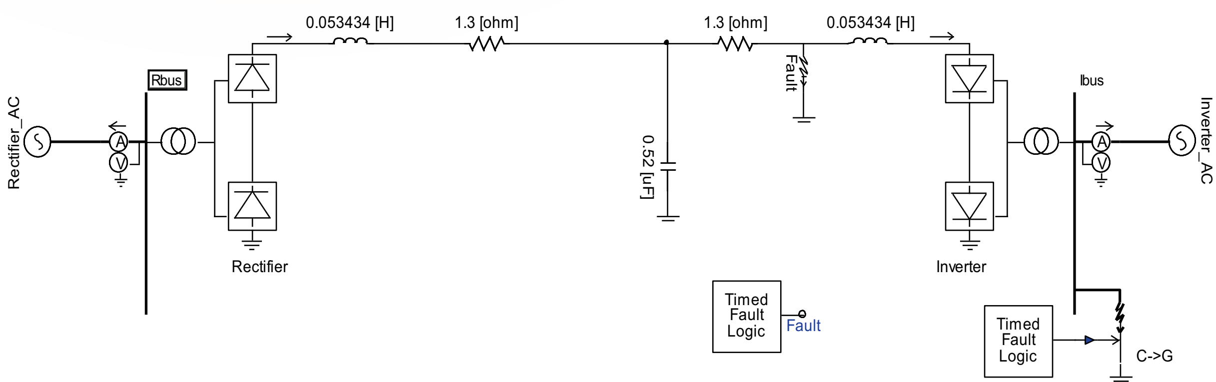

Figure 2 Two terminal CSC-HVDC system

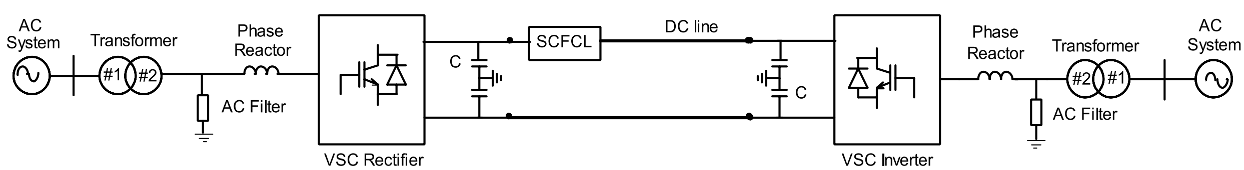

Figure 3 VSC-HVDC system with SCFCL

Of late, the VSC-HVDC systems have gained enormous importance due to the fact that they are immune to commutation failure…

In the CSC-HVDC link, the controllers are very efficient and strictly speaking, SCFCL is not necessary. However, these are very essential for extending the system operation to a multi-terminal HVDC network. The quick response characteristics can overcome the problem of absence of circuit breakers and that it is possible to establish MTDC systems.

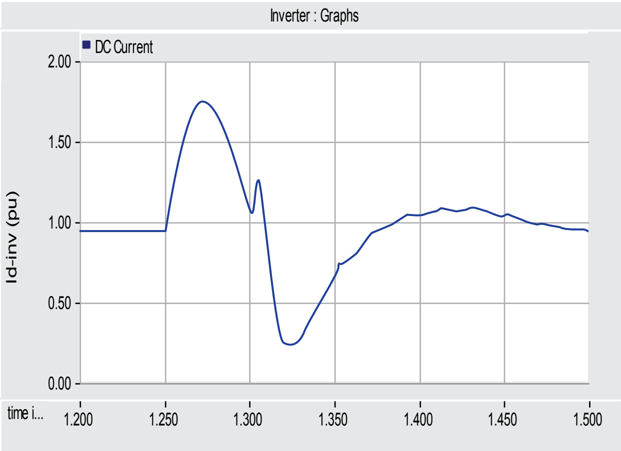

Figure 4a DC current without SCFCL

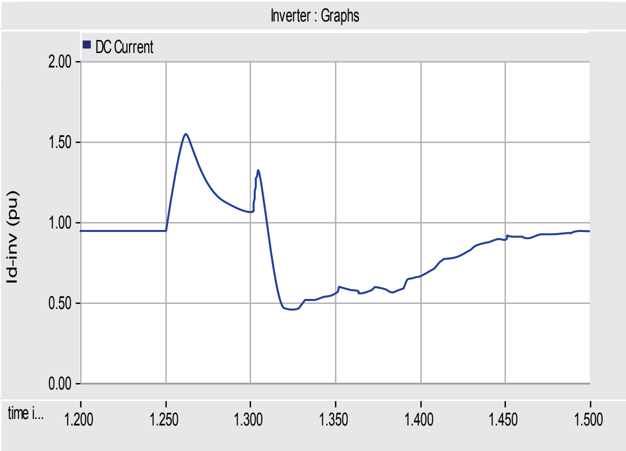

Figure 4b DC current with SCFCL

Of late, the VSC-HVDC systems have gained enormous importance due to the fact that they are immune to commutation failure, control active and reactive powers independently, allow connection to passive AC loads, help in power quality control, require lower foot prints and offer modular design. This opens up various application areas, such as integration of wind power forms, power supply to islands, feeding passive loads, city centre in-feed and multi terminal DC grid operation.

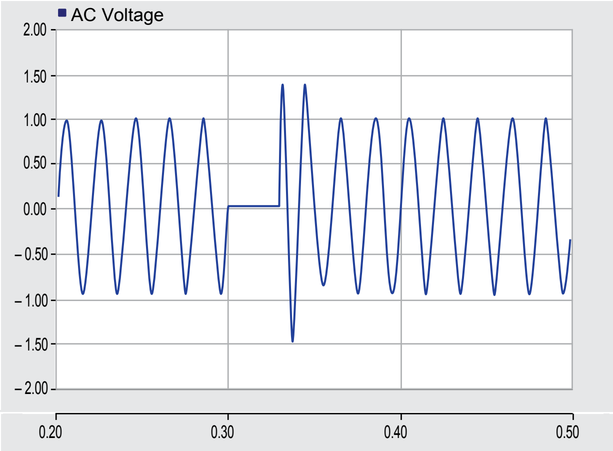

Figure 4c AC voltages at inverter bus

The difficulty with these systems is that they cannot withstand DC line faults and accordingly are used only for underground cable transmissions. The protection of VSC-HVDC systems in overhead line applications is of utmost concern and has attracted many researchers to come up with different solutions. The study of protective devices and their recovery characteristics are discussed in detail in [6], [7].

In this context, SCFCL can be a technically and economically attractive alternative [8]. The transient analyses of a VSC-HVDC system, including SCFCL on the DC side for various fault conditions, are shown in Figure 5.

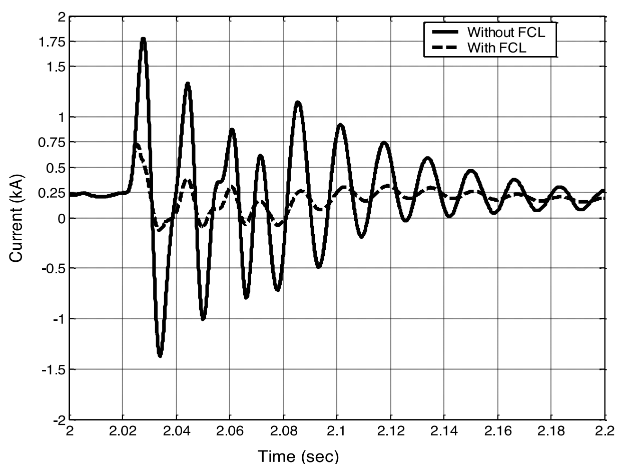

Figure 5a Single line to ground fault

For single line to ground fault at the inverter bus, the SCFCL helps reduce the DC current from 1.75 kA to 0.75 kA, as shown in Figure 5a.

For three phase to ground fault at the inverter bus, without SCFCL, the DC line current reaches the maximum value of 2.75 kA. Inclusion of SCFCL resulted in limiting the peak to about 0.8 kA. This is indicated in Figure 5b.

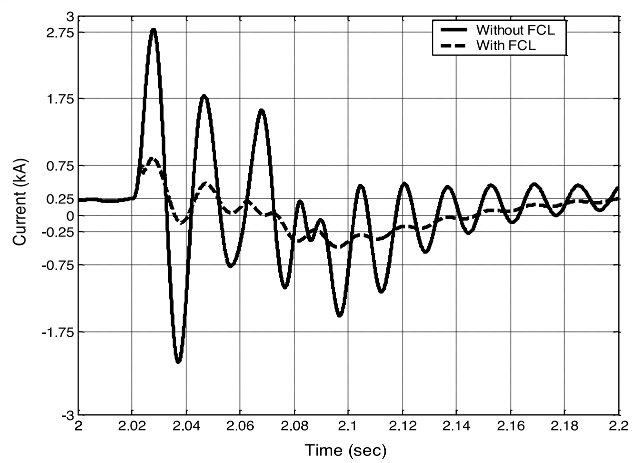

Figure 5b Three phase to ground fault

The protection of VSC-HVDC systems in overhead line applications is of utmost concern…

When DC line to ground fault occurs on the DC side of inverter, the DC line current rises sharply reaching the positive peak of about 8 kA without SCFCL. When the SCFCL is connected on the DC side of the rectifier, the peak value is reduced to 2.5 kA. This is shown in Figure 5c.

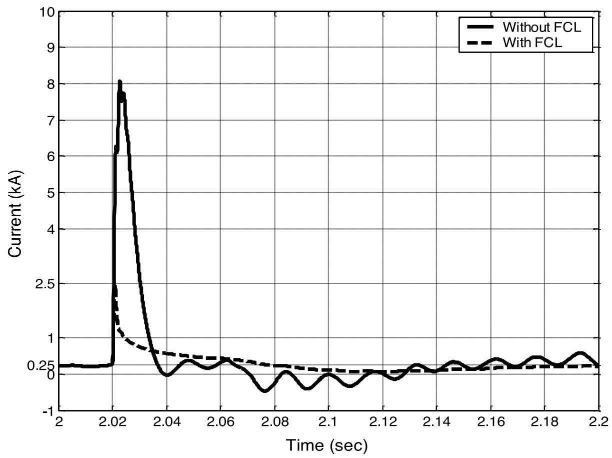

Figure 5c DC line to ground fault

From the above results, it is observed that the peak value of the DC current is reduced to a low value within half a cycle. This is significant in case of DC line faults, thus indicating that it is possible to use overhead lines for VSC-HVDC transmission.

Conclusions This work has successfully integrated and evaluated the performance of an HVDC system with SCFCL. The transient analysis is carried out for different AC/DC faults. The focus of this paper is to evaluate the performance of SCFCL for DC line fault in a VSC-HVDC system which results in large fault current. It is concluded that the SCFCL can indeed act as an efficient protective device for VSC-HVDC systems with overhead lines.

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A Case Study for Over-Voltages in a 400kV Substation Caused by Direct Lightning Strikes

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In power systems, lightning is one of the most serious causes of over-voltages. Every year there are several million lightning discharges occurring all over the world. These over-voltages may cause flashovers and damage to the equipment in substations. Hence, it is essential to select the electrical strength of the equipment so as to prevent equipment insulation damage. It is recommended to use protective devices like surge arresters to save the equipment from insulation breakdown. Hence, the location, number and size of the surge arresters are important to control the lightning over-voltages in substations. PSCAD™ software was used to investigate over-voltage phenomena due to lightning surge. The case study of a typical 400kV substation is carried out to demonstrate the impact of lightning over-voltages and how the ratings of lightning arresters are decided for the substation. The simulation results verify that the proposed location and number of surge arresters are adequate to meet the requirement of equipment insulation levels.

Lightning Over-Voltage Study A lightning surge due to lightning stroke generates over-voltage waves, which may enter a substation either by direct stroke or as travelling waves over the incoming transmission lines. The substation's first few towers from the station are provided with adequate shielding protection from direct strokes and thus allowing only travelling waves from the lines to enter the station. In this study, the lightning surge has been applied at a tower which is at a distance of 300m from the station. The system BIL is 1425 kVp for a 400kV system. Any lightning over-voltage in the system (direct on the phase conductor or through back flashover after a strike on the earth wire) which causes over-voltage beyond this magnitude will result in a flashover, thereby reducing the over-voltage level considerably, at the flash point itself. The value of direct stroke current is calculated with the help of the Brown-Whitehead model, considering the geometry of tower and maximum shielding failure. The calculated value of direct stroke current is 16kA. However, in a worst case scenario for simulation, the direct stroke current of 20kA (8/20μs) is considered.

System Model The system layout is such that a lightning stroke current has been applied at a tower, which is situated at a distance of 300m from the station, and travelled up to GT through the switch-yard. All the substation equipment is represented by their stray capacitance values. For transmission lines, aluminium buses and phase conductors, the frequency dependent phase model is used. As we know, the lightning strike is probable only on one of the three phases at a time. Hence, lightning surge current is applied on only one phase (Y-phase). The simulation diagram for the substation model considered for the lightning over-voltage study without surge arresters is shown in Figure 1.

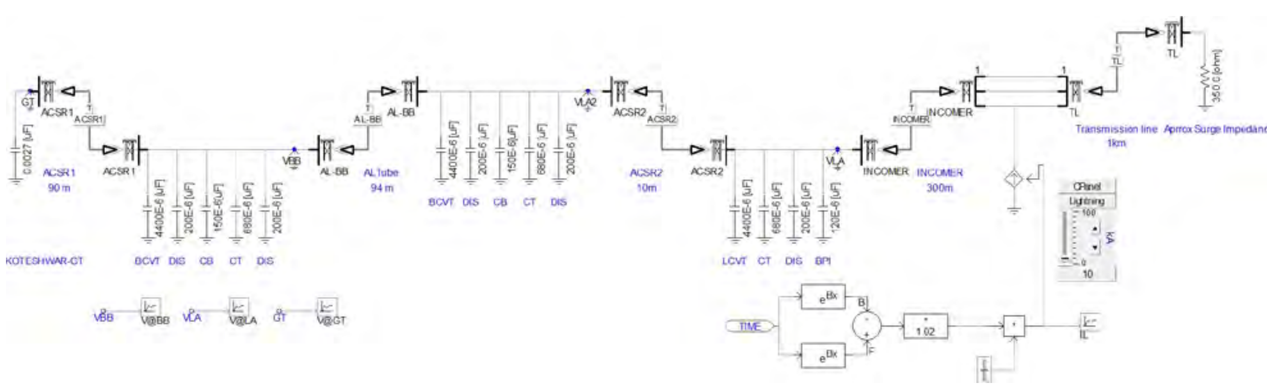

Figure 1 Substation model for lightning over-voltage study

Study Criteria The lightning impulse withstand voltage of the equipment in the substation, including the transformers, is 1425 kVp. The protection level of the arrester is taken to be 975 kVp for 20 kA.

The protection margin at 20 kA current is therefore (1425-975)/975=46.15%. However, the above margin is valid at arrester terminals only. The over-voltage at the equipment terminal increases with the latter's distance from the arrester. In the case of transformers, arresters are provided very close to them and therefore provide good protection. For switchyard equipment, which may be at a considerable distance from the arrester, the protective levels may be higher, thus reducing the margin. A minimum safety margin of 5% is stipulated by IEC 71-2 for external insulation. An atmospheric correction factor of 1.080 is to be applied for 630m (i.e. altitude from sea level) for switchyard terminal and atmospheric correction factor of 1.072 is to be applied for 570m for GT terminal. We consider the worst case of 630m (i.e. altitude from sea level) and thus the required margin is (1+0.5) * 1.080 = 1.134. For internal insulation, minimum safety margin is specified to be 15% and in this case, the atmospheric correction factor is not applicable. Thus, for the transformer, the minimum safety margin required is (1+0.15) = 1.15. In the case of lightning over-voltage, the voltages measured at different points in the substation should be below 1425/1.134 = 1255 kVp, and at transformer terminals it should be below 1425/1.15 = 1240 kVp. The study shall ensure that over-voltage level at the equipment terminals is less than this value for all cases of lightning over-voltage.

Cases Studied The over-voltage at any point is a combination of the incident surge and the reflected waves from different points in the system. Various combinations of LAs were therefore considered in order to check the effect of reflected surges at different points.

The following cases are studied for the lightning over-voltages study:

1. Substation without surge arresters at GT and line side
2. Substation with surge arresters at GT and line side

Further, the study focuses on following three locations for analyzing the impact of over-voltages:

1. Generator Transformer (GT) terminal
2. Main bus
3. Line side

   The cases considered for the present study are tabulated as in Table-1

Case 1 The lightning stroke current is considered to strike at a distance of 300m from the substation and the lightning surge travels towards the substation. In this case, no lightning arresters are connected to the substation and GT terminal. The system model for Case 1 is shown in Figure 1. The result shows that the voltage at GT terminal and line side reaches a peak of 5824.6kV and 5711.64kV respectively. Figure 2 shows the voltage at various locations of substation.

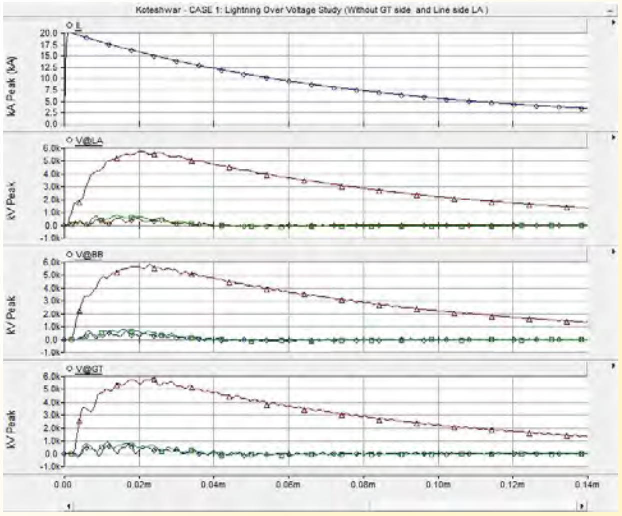

Figure 2 Voltages at various locations (Case 1)

LAs provide an adequate safety margin for different equipment…

Case 2 The lightning surge is considered to strike at a distance of 300m from the substation and continues to travel towards the substation. In this case, lightning arresters are considered at the substation, on the outgoing transmission line and at the transformer terminal. The system model for Case 2 is shown in Figure 4.

The results show the maximum over-voltage of 683.31kV at the Generator Transformer terminal. Corresponding to a lightning impulse BIL of 1425kV for the substation, the lowest limit of lightning over-voltage with a safety margin of 20% is 1140kV which is less than our measured value. It is noted that LAs provide an adequate safety margin for different equipment. Figure 3 shows the voltage at various locations and Figure 5 shows the discharge current and energy dissipation of lightning arresters connected to the system.

From the results obtained in Figures 2 and 3, we can deduce that the LA on the GT and line side can take care of the surges coming from the line side. In Case 1, the measured voltage at the switchyard line side and GT terminal side are not within the limit (1140kV).

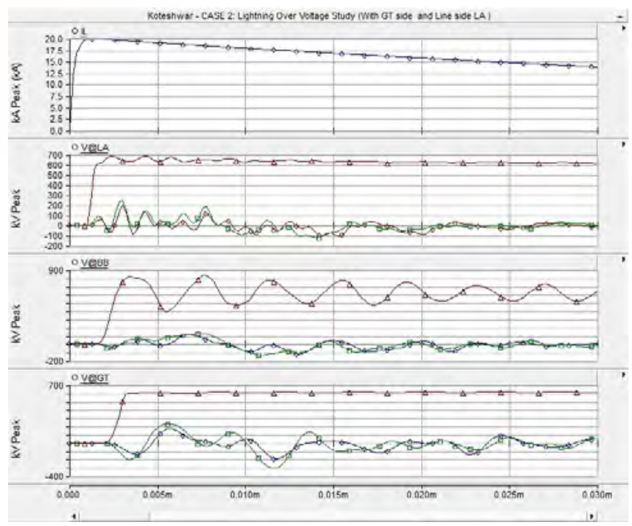

Figure 3 Voltages at various locations (Case 2)

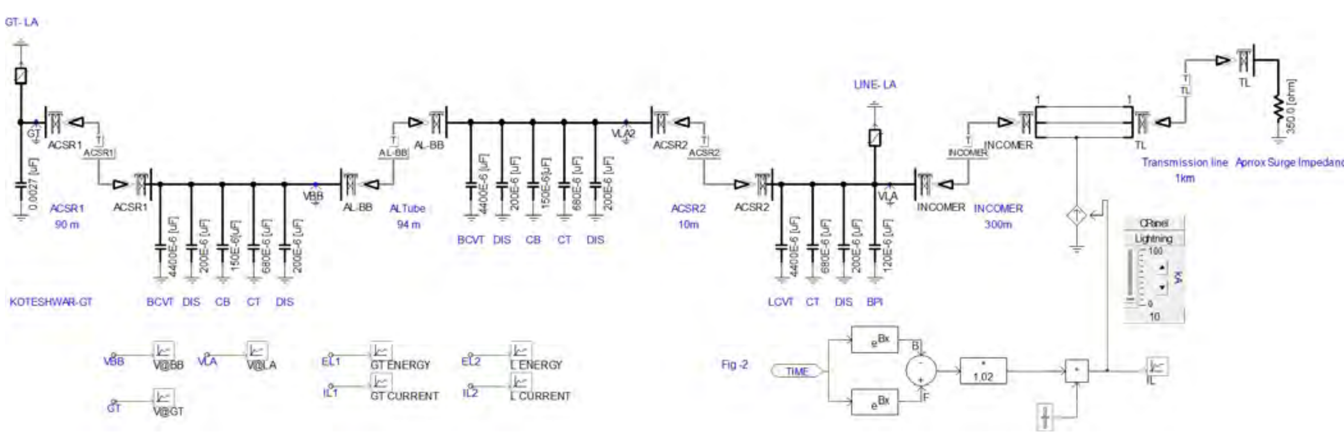

Figure 4 System model for Case 2

If the LAs at the switchyard line side and GT terminal are connected, then the measured voltage at this point decreases to 618.66kV and 683.31kV respectively, which falls within the limit. Table 1 shows the discharge current and energy dissipated value of surge arresters.

Conclusion The paper presents the modelling details of a substation for lightning over-voltage studies. The results of the simulations for lightning surges transferring through a substation using PSCAD™/EMTDC™ are presented. Two case studies have been performed to determine the rating and location of surge arresters. Based on these studies, it is observed that 390 kV LAs are required to be connected at the GT terminal and line side of the switchyard to limit the over-voltages to safe levels. The energy rating of 390 kV LA should be more than 356.32/390=0.913kJ/KV and the selected energy rating of 8kJ/kV is suitable. The discharge current rating of 20kA surge arrester is chosen.

In order to adequately protect the transformer and other substation equipment, it is necessary to provide surge arresters at the following locations in the substation.

- Close to every transformer
- On each of the outgoing and incoming feeders of the substation

Description	GT Side			Outgoing line side		
	kV	kJ	kA	kV	kJ	kA
Case 1	5824.6	-	-	5711.64	-	-
Case 2	683.31	316.71	6.868	618.66	356.32	18.79

Table 1 Measured values in different cases

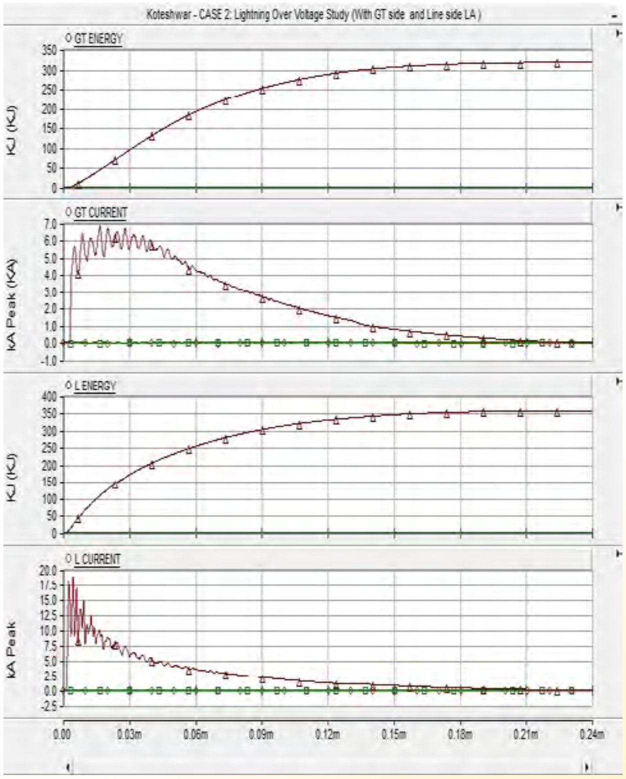

Figure 5 Discharge current and energy dissipation of lightning arresters (Case 2)

2012 PSCAD™ European User Group Meeting

Alyson Teterenko, Manitoba HVDC Research Centre

PSCAD User Group Meetings (UGMs) play an important role for our PSCAD users. They allow users to share best practices with peers and learn from leading industry and subject matter experts. They provide tremendous networking opportunities while users receive the latest product information.

As well, it is essential for developers of PSCAD to maintain a strong relationship with our users, as it is their feedback that drives new product development. The UGM gives developers a unique opportunity to sit down with users on a personal level and discuss their needs now and what they foresee for the future.

Response has been very good from the North American UGM in 2009, the European UGMs in 2010 and 2012, and the China and India UGMs in 2012.

This year's PSCAD EUGM was held from March 27 – 30, 2012 in Castelldefels, Spain at the Gran Hotel Rey Don Jaime. The conference facilities and grounds were not only very accommodating, but quite beautiful.

As in 2010, the 2012 EUGM was a very successful event with just over 50 attendees, representing 22 different countries. The three day meeting consisted of users' application presentations, PSCAD presentations, and a choice of two different tutorials. New to this event, attendees were given the option of participating in a *Fundamentals of PSCAD & Applications* tutorial before the actual UGM commenced.

The meeting began with our key note speaker, Dr. Ani Golé, Ph. D., P. Eng., giving us a fascinating in-depth look at the history of PSCAD. Prof. Ani Golé holds the NSERC/Manitoba Hydro Industrial Research Chair in Power Systems Simulation at the University of Manitoba, Canada. He has over 30 years experience in HVDC Transmission and FACTS technologies and in addition to his University employment, he has worked at Manitoba Hydro, Hydro Quebec (IREQ), and the Manitoba HVDC Research Centre. He has a long term involvement with the development of off-line and real–time tools for Power System simulation, and was a member of the original design team that developed the PSCAD™/EMTDC™ program.

The key note speech was followed by user presentations. Topics included Solar PV, wind applications, and more. All presentations were engaging, and followed by many questions and discussions. We wish to send a special thank-you to the following presenters, as their involvement contributed greatly to the event's success and made it even more meaningful:

- *Francisco Jiménez Buendía,* Gamesa
- *Janne Leminen,* ABB Finland
- *Bogdan-Ionut Craciun,* Aalborg University
- *Oliver Glitza,* SMA Solar Technology AG
- *Toumas Rauhala,* Fingrid Oyj
- *Jianping Wang,* ABB Sweden
- *Lei Wu,* Einhoven University of Technology

We welcome you to contact us if you are interested in presenting at a future UGM.

With so many users in attendance, we took the opportunity to present our latest and upcoming features for PSCAD. It is a fantastic way to get feedback and suggestions for these new developments, while creating excitement about our upcoming release. It was our pleasure to introduce the following new developments:

- High performance computing using grid technologies
- Root control – Multi-EMTDC and high level control strategies

Additionally, we discussed ways to improve how our users can continue to maintain a strong relationship with us outside of the UGM and have their opinions heard through:

- Email
- Our maintenance program
- Beta program
- The PSCAD user portal
- Forum

After a day and a half of presentations, attendees had the choice of one of two additional tutorials:

- *PSCAD and Power System Applications* taught by Ozge Oz (CEDRAT S.A.) and Dharshana Muthumuni (Manitoba HVDC Research Centre)
- *Applications of FACTS and HVDC* taught by Dr. Ani Golé (University of Manitoba)

Thank you to those who joined us at a banquet the first night overlooking the town of Castelldefels and the Mediterranean Sea. It was here that personal connections and friendships were made, many of which will surely continue after the EUGM.

Based on the number of times we have been asked when the next UGM will be, we are proceeding with plans for more, including Canada 2013 and Europe 2014. See you there!

Special thanks to those who helped us make the event so fantastic!

- *Vicente Aucejo and Juanjo Salavert (INDIELIC)*
  – On the ground coordination of arrangements within Spain.
- *Dr. Ani Golé (University of Manitoba)*
  – Special guest speaker and instructor of the *Applications of FACTS and HVDC* tutorial on March 29 & 30.
- *Ozge Oz (CEDRAT S.A.)*
  – Instructor of the *Fundamentals of PSCAD and Applications* tutorial on March 27.

2012 PSCAD™ and RTDS® India Conference

Nayak Power Systems Pvt. Ltd., Bangalore, India

Nayak Power Systems in collaboration with the Manitoba HVDC Research Centre and RTDS Technologies hosted the 2012 PSCAD and RTDS India Conference on January 11-13 at The LaLiT Ashok, Bangalore, India.

More than 70 new and existing PSCAD and RTDS users participated in a 3-day conference comprising of user presentations and short tutorials on a wide range of applications. Tutorials covered several popular topics, including modeling of:

- HVDC and FACTS
- Wind Power Systems
- Harmonic Analysis
- Insulation Co-ordination Studies
- Custom Components Development

Discussions were scheduled with the developers and engineers at the end of each day which helped many users receive clarification on specific topics.

We want to thank our distinguished guest and user Professor Ani Golé. As one of the original developers of EMTDC™ and a continuing force and inspiration, his keynote speech covering the history and development of PSCAD/EMTDC and RTDS, and his insight on the future direction of power system simulation tools was highly appreciated by all participants. Thank you to all the participants and presenters for making the event a rewarding experience for all.

For further information on the proceedings of the conference, please contact *sales@pscad.com*

2012 PSCAD and RTDS India Conference 11–13 January, Bangalore, India.

2012 PSCAD™ User Group Meeting, Beijing, China

Alan Wang, Manitoba HVDC Research Centre

Beijing Tianyan Rongzhi Software Co. Ltd., in collaboration with the Manitoba HVDC Research Centre, hosted the 2012 PSCAD User Group Meeting in Beijing, China with 73 users in attendance.

Presentations by users included:

- The applications of sub synchronous resonance in power system
- The applications of analysis of converter accidents
- The application of traction power supply system power quality compensation
- The application of reactive power compensation device at home and abroad

Presentations by the Manitoba HVDC Research Centre included:

- Demonstration and discussion of selected new features of PSCAD 4.5.0
- MMC-HVDC transmission
- Sub-synchronous resonance investigation of wind farm
- Topics on insulation coordination

Thank you to all the participants and presenters for making the event a rewarding experience for all. For further information on the proceedings of the conference, please contact *sales@pscad.com*

2012 PSCAD User Group Meeting Beijing, China.

From the PSCAD™ Support Desk – Shortcut Keys

Manitoba HVDC Research Centre

The difference between new users and advanced professional users of PSCAD is the use of the many shortcuts (or hotkeys) available in the software. Hotkeys help to reduce the 'amount of clicks' required to perform specific tasks, thus making much more efficient use of your time and efforts.
The keyboard shortcuts include:

General – The 'Ctrl' key may be dropped where indicated (i.e. [Ctrl +]) if **Enable Cut/Copy/Paste without 'Ctrl' Key** in the Workspace Settings is selected.

Shortcut	Description
[Ctrl +] X	Cut selection
[Ctrl +] C	Copy selection
[Ctrl +] V	Paste selection
R	Rotate selection right
L	Rotate selection left
M	Mirror selection
F	Flip selection
S	Set component sequence. Note that **Assign Sequence Numbers Automatically** must be enabled in the Canvas Settings dialog.
Ctrl + A	Select all
Ctrl + Z	Undo
Ctrl + Y	Redo
Ctrl + O	Load project
Ctrl + N	New project
Ctrl + S	Save active project
Ctrl + G	Global Substitutions dialog
Ctrl + U	Unload the selected project from the workspace
Ctrl + W	Invoke/cancel wire mode
Esc	Cancel action
+	Zoom in
-	Zoom out
Ctrl + Shift + Left Mouse Hold	Pan (dynamic scroll)
Ctrl + Left Double Click	Edit definition of selected component or module
Ctrl + Right Click	Invoke the library pop-up menu system
Left Double Click	Edit properties of selected component or module
Backspace	Navigate backwards
Ctrl + Backspace	Navigate up to parent canvas
F5	Refresh canvas
F1	Invoke the help system
← → ↑ ↓	Scroll canvas horizontally and vertically

Wires – To apply any of the following shortcuts, simply move your mouse Pointer over a wire.

Shortcut	Description
V	Insert a wire vertex
I	Reverse wire vertexes
D	Decompose wire

Plotting – To apply any of the following shortcuts, move your mouse pointer over a plot area. Note that in some instances, the graph must be selected.

Shortcut	Description
Insert	Insert an overlay graph
+	Zoom in to graphs
-	Zoom out to graphs
P	Zoom previous
N	Zoom next
X	Zoom x-axis extents
E	Zoom x-axis limits
Y	Zoom y-axis extents
U	Zoom y-axis limits
R	Reset all extents
B	Reset all limits
Ctrl + Left Mouse Hold	Zoom horizontal aperture
Shift + Left Mouse Hold	Zoom vertical aperture
Left Mouse Hold	Zoom to box (simultaneous horizontal and vertical)
G	Toggle grid lines
I	Toggle tick marks
K	Toggle curve Glyphs
M	Show markers
X	Set X marker
O	Set 0 marker
L	Toggle marker lock-step
F	Toggle frequency/delta view
Q	Show x-intercept
W	Show y-intercept
C	Show cross-hairs (follows curve traces)
Space Bar	Switch curves while in cross-hair mode

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Meet the Team!

Manitoba HVDC Research Centre

The Manitoba HVDC Research Centre prides itself on its excellent customer support and service. Our success is a direct result of our client focused efforts. We are committed to providing our clients with the best possible support to ensure optimum success with our products and services. *Meet the Team* will be a regularly published addition to the *Pulse* Newsletter to introduce our experienced team members. This publication features Kristen Benjamin and Lawrence Arendt; just a few of the dynamic staff members we are fortunate to have at the MHRC.

Kristen Benjamin
Customer Service and Marketing

Since 2007, Kristen has been working directly with PSCAD clients. Many of you have dealt with Kristen through sales, maintenance or suppport. Always with a smile, she is responsible for the renewal of PSCAD maintenance contracts, as well as triage for PSCAD support enquiries.

Kristen has a background in business, graphic design, photography and marketing.

Lawrence Arendt
Senior Software Engineer

Lawrence started with the Manitoba HVDC Research Centre in 1988 and is the longest serving employee at the Centre. He graduated with an M.Sc. (E. Eng.) in 1996. He worked on the development of the RTDS and RTP hardware and software. He is currently working as a Senior Software Engineer with the PSCAD Development Team and has worked with the licensing and deployment of PSCAD since 1999.

Lawrence enjoys spending time with his family and his two dogs.

Visit our New Website at *www.hvdc.ca*

Expanding Knowledge

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

Fundamentals of 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
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, modeling and advanced topics. *Duration: 4–4.5 Days*

AC Switching Study Applications in PSCAD™
Fundamentals of switching transients, modeling 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*

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

Lightning Coordination & Fast Front Studies
Substation modeling 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*

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

Modeling and Application of FACTS Devices
Fundamentals of solid-state FACTS systems. System modeling, control system modeling, converter modeling, and system impact studies. *Duration: 2–3 Days*

Transmission Lines & Applications in PSCAD™
Modeling of transmission lines in typical power system studies. History and fundamentals of transmission line modeling, discussion on models, such as Phase, Modal, Bergeron and PI in terms of accuracy, typical applications, limitations, etc., example cases and discussion on transposition, standard conductors, treatments of ground wire, cross-bonding of cables, etc. *Duration: 3 Days*

Wind Power Modeling and Simulation using PSCAD™
Includes wind models, aero-dynamic models, machines, soft starting and doubly fed connections, crowbar protection, low voltage ride through capability.
Duration: 3 Days

Connect with Us!

May 5–8, 2013
AWEA Windpower 2013 Conference & Exhibition
http://www.windpowerexpo.org
McCormick Place, Chicago, Illinois, USA

July 18–20, 2013
IPST
http://www.ipst2013.com/
University of British Columbia, Vancouver, British Columbia, Canada

July 21–25, 2013
IEEE PES General Meeting
http://pes-gm.org/2013/
Vancouver Convention Centre, Vancouver, British Columbia, Canada

More events are planned!
Please see *www.pscad.com* for more information.

PSCAD™ Training Sessions

Here are a few of the training courses currently scheduled. Additional opportunities will be added periodically, so please visit *www.pscad.com* for more information about course availability.

April 23–25, 2013
Wind Power Modeling and Simulation using PSCAD™

May 14–16, 2013
Applications of PSCAD™ and Transient Studies

June 4–6, 2013
HVDC Theory & Controls

All training courses mentioned above are held at the Manitoba HVDC Research Centre, Winnipeg, Manitoba, Canada
training@pscad.com *www.pscad.com*

Please visit Nayak Corporation's website *www.nayakcorp.com* for courses in the USA.

July 2–5, 2013
Fundamentals of PSCAD™ and General Applications
Nayak Corporation, Princeton, New Jersey, USA

Please visit Nayak Power Systems Pvt. Ltd.'s website *www.nayakpower.com* for more information on courses in India.

May 6–7, 2013
Fundamentals of PSCAD™ and General Applications
Nayak Power Systems Pvt. Ltd., Bangalore, India

August 5–6, 2013
Fundamentals of PSCAD™ and General Applications
Nayak Power Systems Pvt. Ltd., Bangalore, India

For more information on dates, contact training@pscad.com *today!*

If you have interesting experiences and would like to share with the PSCAD™ community in future issues of the *Pulse,* please send in your article to *info@pscad.com*