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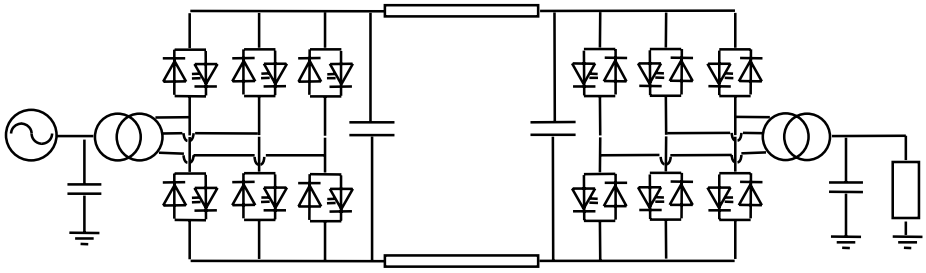
VSC Transmission - the way of the future?

VSC Transmission or Voltage Sourced Converter Transmission is now a reality and we will be seeing more installations as its special features are applied. The first VSC Transmission systems have been built by ABB under the designation "HVDC Light." Why is it such an important development? Do you understand its operation and design?

Voltage sourced converters are not new. They are applied in FACTS controllers, the STATCOM and the UPFC (Unified Power Flow Controller).

If voltage sourced converters are located apart with a dc transmission line or cable between them, we have VSC Transmission. One decided advantage is achieved when cables can be applied. Because VSCs have uni-directional back diodes with each valve in each converter, whether rectifier or inverter, the dc voltage on each cable can never reverse its polarity. Consequently the problem of residual space charge in dc cables is diminished to allow minimal insulation, and using an extrusion process, the cables are small and light and relatively cost effective.

With medium voltage VSC Transmission there is the ease in which small and light cables can be laid underground. At the IEEE Winter Power Meeting held in New York this past February, we heard the exciting application of a pioneering VSC Transmission interconnection (HVDC Light) being built in Australia between New South Wales and Queensland. Because the line will be underground cable, environmental considerations and licensing compared with overhead transmission will result in a significantly shorter inservice time. A report on the project known as "Directlink" is given in the ABB Newsletter "PowerLink," Vol 1999 No.1. The 180 MVA underground cable will be laid in existing rights-of-way consisting of established streets, transmission line corridors and beside railway tracks.



Representation of a simple configuration of a VSC cable transmission system consisting of 2 level, 6 pulse width modulation (pwm) VSC converters.

VSC Transmission also inherently has the properties of FACTS controllers. These include:

1. Independent ac voltage control at each terminating bus with the same capabilities as having STATCOMs at each end.

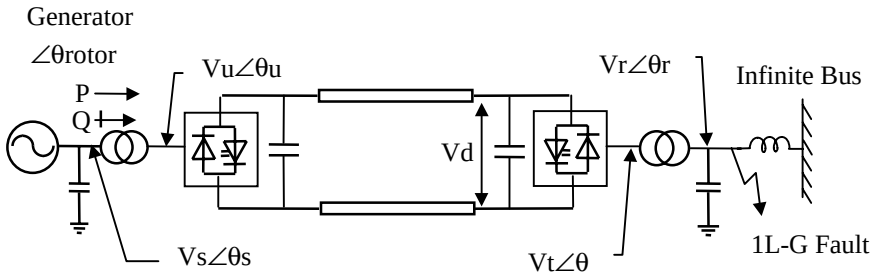
2. Fast response power control can be used to increase damping of electromechanical power oscillations in the ac system to which it is connected to.

3. The receiving end may be a load without any other form of generation present. The VSC inverter can form an ac supply at specified frequency and voltage without any other equipment required.

With such very favourable advantages and if price is reasonable, medium voltage VSC Transmission may work well in an ac network. Hence the need for VSC transmission to do its part in contributing to strengthening system synchronism.

VSC Transmission as an emerging technology has little information in the literature to assist in design, except perhaps by a turnkey contract to an equipment supplier. Engineers and transmission experts who desire to keep current in this technology are at a disadvantage in this respect.

VSC Configuration. There are many different configurations



Control Functions:

1. Power P determined by adjusting ∠θu as a function of ∠(θs-θr)
2. Ac voltage Vs determined by generator exciter.
3. Reactive power Q determined with pwm control adjusting Vu
4. Dc voltage Vd determined by adjusting ∠(θt-θr)
5. Ac voltage Vr determined with pwm control adjusting Vt
6. Damping of ∠θrotor achieved by modifying power P as a phase advanced function of ∠θs-θr) when adjusting ∠θu.

Example to demonstrate VSC Transmission with controls to emulate ac transmission line characteristics. A 1L-G fault applied as a test.

possible for voltage sourced converters. They may be 2 level or multi-level bridges. The main switching device may be a GTO of one form or another, or an IGBT. They may be switched on and off once per cycle or may be pulse width modulated (pwm). Generally whatever VSC configuration is applied, it will behave in a similar manner and apply strategies for harmonic cancellation or elimination. They may be three phase based or single phase based.

It is sensible to allow the equipment suppliers to propose their configuration of choice for a given application. However, it is useful to understand the comparative advantages and disadvantages of the various configurations which might be offered.

Control. If pwm is applied, then at least 4 parameters can be virtually independently controlled in a VSC Transmission system application.

If the receiving end load has no ac supply, then the VSC inverter can control frequency and ac voltage. The sending end VSC may control dc line voltage and ac bus volts.

If the receiving end load is an established ac system, then the VSC inverter can control receiving end ac bus volts and dc line volts. The sending end VSC can control power and sending end ac bus volts or reactive power.

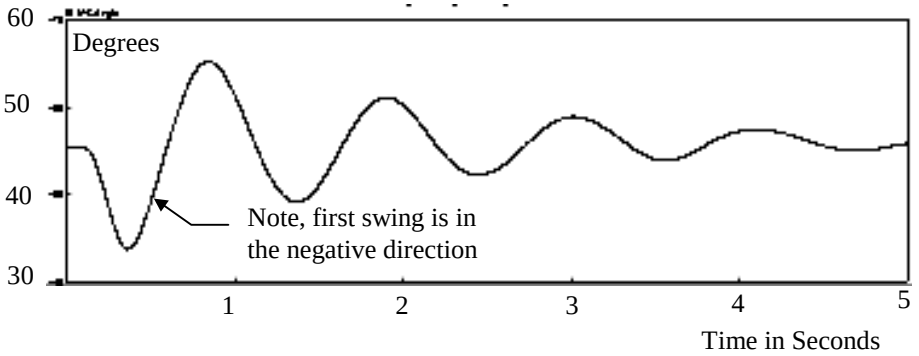
The choice of controlled variables will be application dependent and may require some advanced study to determine and define.

Ac Line Characteristics. Faster installation schedules, environmental advantages and easier licensing may favour VSC transmission ahead of conventional overhead ac lines. It might be argued that the synchronizing property of ac transmission would be lost if VSC transmission is utilized.

This is not necessarily so. The excellent controlling capabilities of VSC transmission can be applied to provide not only strong synchronizing power, but also substantial system damping as well.. There is an added advantage over ac transmission in this respect: If a severe disturbance threatens system synchronization, a VSC transmission line will provide STATCOM like voltage support at its terminations, as well as maintain a maximum power characteristic when it is needed most.

In other words, VSC transmission is the ultimate FACTS controller, applying ac voltage control at its terminating busses, independent power and phase shift control, synchronization and system damping. No other transmission link or FACTS controller is as all encompassing.

Explore VSC Transmission for Yourself. 2 level, pwm VSC transmission examples can be freely downloaded along with the Personal Edition of PSCAD/EMTDC V3 from the Centre's website. Explore the controls which can be used to achieve the significant properties of VSC transmission. When you down-load, VSC Transmission with a dead receiving end load is in "hvdc\vltg_conv\low_vltg_hvdc.psc". The VSC Transmission model with ac characteristics is found in "hvdc\vsc2\VSCTrans.psc".



Rotor angle swing of a generator radially feeding VSC transmission with ac transmission characteristics for 1L-G fault in receiving end ac system

Can fluorescent lights and infrared controllers co-exist?

IR/EMI interaction research has been undertaken at the Manitoba HVDC Research Centre as a result of undesirable interference observed between some new fluorescent lighting installations and remote controllers for electronic equipment

Recently, the Manitoba HVDC Research Centre was awarded a research grant from Manitoba Hydro to study the effects and interactions of Infrared Radiation (IR) and Electromagnetic Interference (EMI) emitted by common linear fluorescent lamps. This is in collaboration with the Business Engineering Services Department of Manitoba Hydro.

The Power Quality Group at the Centre has been commissioned to research problems associated with IR and EMI. Remote controllers for TVs, VCRs and Teleconferencing Equipment use IR as a carrier signal when transmitting. The transmission can be confused if some linear or compact lamps are turned on and are located in the proximity of the IR receiver. IR emitted from these lamps, can interact and combine with this transmission, cause command misinterpretation (e.g. a volume-up when pressing volume-down) or the command may be lost entirely.

In the past, magnetic ballasts operated fluorescent lamps at fundamental frequency (50 or 60 Hz). In recent years however, lighting manufacturers have switched to mostly electronically controlled ballasts, capable of operating lamps in the 20-50 kHz range. It was found that by increasing the operating frequency of lamps into this range, a 10% increase in light output per watt would be achieved.

Unfortunately, fluorescent lamps not only produce light; a small amount of electromagnetic interference and infrared (heat) is also emitted during normal operation. The IR emitted - always present as long as the lamps are on - is effectively amplitude modulated according to the shape and frequency of the lamp current and energy.

John Nordstrom with the fluorescent lighting ballast test set.

Since IR is a form of energy, its magnitude is always positive. Therefore, the IR magnitude reaches a maximum during both the positive and negative cycles of lamp current - resulting in an IR frequency that is double the operating frequency.

This frequency range overlaps that of most remote control transmitter carrier signals. If the IR frequency of the lamps used in an office space overlaps frequencies used by, for instance, teleconferencing equipment remote controllers used in that space, problems may occur.

Norm Tarko and John Nordstrom, members of the Power Quality Group at the Centre, have been working with various organizations experiencing these problems. Their efforts are enhanced by a fluorescent lamp ballast test set specifically designed to efficiently test power quality indices related to electronic and magnetic ballasts.

In addition to ballast input properties, the test set allows for the measurement of lamp current, voltage, power and lamp frequency. The test set can also be used to conduct experiments on light and IR intensity, as well as Radio Frequency Interference (RFI). They have built one test set and are in the process of developing new instruments to assist them in the ongoing IR interaction research.

Over the past several months, the Power Quality Group has collected data from commercial and residential areas that have reported IR interaction problems. They are working with designers installing new lighting systems who would like to avoid future difficulties with electronic equipment. By collecting case studies and undertaking site tests, they hope to find a problematic pattern in their analysis - from which they hope to develop simple, cost-effective solutions.

If you are interested in this problem, and you think we can help, please get in touch with us.

About PSCAD/EMTDC Version 3 - the Professional's tool for transients simulation.

An interactive precision simulator of networks, machines and controllers and a platform for users to develop their own models and systems in FORTRAN and C. It has long been recognized that the progressive engineer is limited in tools to explore advanced and new power system concepts and test them for new applications. Advanced information on FACTS, HVDC transmission, active filters, ferroresonance, power electronics etc. is held by too few experts. The purpose of PSCAD/EMTDC is to open these new and exciting technologies up so that first hand experience can be gained by the enquiring engineer for judiciously evaluating new equipment capabilities for critical applications.

The Personal Edition of PSCAD/ EMTDC Version 3 has been available for downloading from the Centre's website since February 1999. Since then continual improvements have been made at the suggestions of users and the simulator has reached the stage in development where the Commercial and Education Editions are now being released. We appreciate the useful suggestions provided and bugs found. We value the input users make in defining and improving the simulator.

Minimum Computer Requirements

- Windows 94, 98 or NT4.
- Netscape or Microsoft Explorer.
- PC with a minimum of 32 Mb RAM and 200 Mb of free Hard Drive space.

Compilers. A FORTRAN compiler is required and the Digital Fortran 90 compiler (Version 5 or 6) is commercially available for use. Alternatively, the GNU Fortran 77 compiler (Public License) can be downloaded free from our website.

The Personal Edition. Has the features of the Educational and Commercial Editions but is limited in capacity. It can be freely downloaded from our website at www.hvdc.ca. What you will download includes:

- Executable Personal Edition of PSCAD/EMTDC V3.
- On-line Help.
- "Getting Started" Manual.
- GNU F77/C Compiler (GNU Public License.
- Network examples of FACTS, Voltage Sourced Converters, active filters, and variable speed drives.

Download Instructions: Go to the Centre's website www.hvdc.ca.

- Click "PSCAD V3 Register Here." You will enter a registration page.
- Please enter the required information. You will immediately receive a PSCAD User Name and Password. Remember these for future downloads when new releases are available.
- With your User Name and Password, access the PSCAD V3 Personal Edition Download site.
- Go to www.hvdc.ca and click on "Download V3."
- Enter the V3 Download area and follow instructions.
- Remember to submit your feedback. Go to www.hvdc.ca, click on PSCAD V3 Feedback," or send email to PSCAD@hvdc.ca.

Educational Edition. Free for Universities and can be downloaded from www.hvdc.ca but a password is required.

- Not to be used for any commercial work unless a commercial license is purchased.
- Only for use at a recognized University.
- 1 license key provided at cost. It will allow network use up to 99 users. A second key may be purchased under special circumstances.
- Limited in capability to 200 nodes.
- Must have MS TCP/IP network protocol installed. This often means a network card must be installed on the PC.

Commercial Edition. If used with the Digital Fortran Compiler, dynamic dimensioning will apply. The first year of maintenance is included in the license fee. Software maintenance beyond the first year is at 10% of the purchase price. Minor updates and patches are free.

- Major updates will be at 50% of the purchase price for licenses where support is purchased.
- Major updates will be at 90% of the purchase price where support has not been purchased.

Unix Version 2 will still be supported as it is an excellent simulator. Unix Version 3 will not be released in the near future. Policies are available to allow Unix V2 users to use and try out PC Windows V3. Contact PSCAD@hvdc.ca for further information.

GOOD SIMULATING.

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