Centre Journal

Volume 9 No 2 | Manitoba HVDC Research Centre | Winter 1996

STATic Synchronous COMpensators : STATCOM

What is a STATCOM? How does it work ? What can it do for our power system? There is really little mystery surrounding these revolutionary power electronics controllers. Understanding a STATCOM from its valve switching to its control performance is best accomplished with visualization of its circuit, controls and operation, now possible through the use of a graphical simulator such as PSCAD/EMTDC.

STATCOMs are based on Voltage Sourced Convertor (VSC) topology and utilize either Gate-Turn-off Thyristors (GTO) or Isolated Gate Bipolar Transistors (IGBT) devices. The STATCOM shown in Figure 1, is a very fast acting, electronic equivalent of a synchronous condensor. If the STATCOM voltage, Vs, (which is proportional to the dc bus voltage Vc) is larger than bus voltage, Es, then leading or capacitive VARS are produced. If Vs is smaller then Es then lagging or inductive VARS are produced. A STATCOM equivalent circuit is shown in Figure 2.

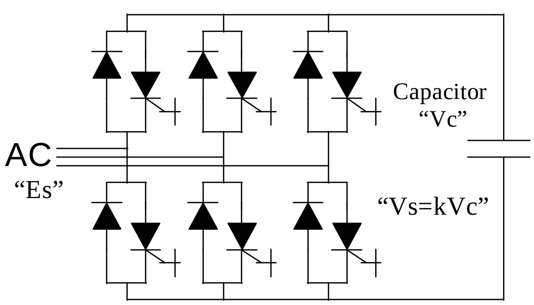
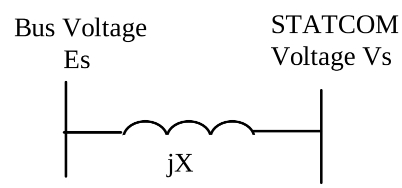


Fig. 1. 6 Pulse STATCOM

The three phase STATCOM makes use of the fact that on a three phase, fundamental frequency, steady state basis, the instantaneous power entering a purely reactive device must be zero. The reactive power in each phase is supplied by circulating the instantaneous real power between the phases. This is achieved by firing the GTO/diode switches in a manner that maintains the phase difference between the ac bus voltage ES and the STATCOM generated voltage VS. Ideally it is possible to construct a device based on circulating instantaneous power which has no energy storage device (ie no dc capacitor). A practical STATCOM requires some amount of energy storage to accommodate harmonic power and ac system unbalances, when the instantaneous real power is non-zero. The maximum energy storage required for the STATCOM is much less than for a TCR/TSC type of SVC compensator of comparable rating.



$$I = (Es - Vs) / jX$$

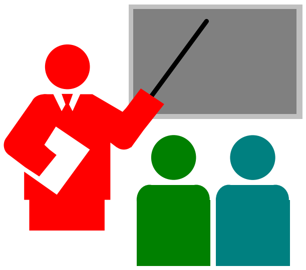
Fig 2. STATCOM Equivalent Circuit

Several different control techniques can be used for the firing control of the STATCOM. Fundamental switching of the GTO/diode once per cycle can be used. This approach will minimize switching losses, but will generally utilize more complex transformer topologies. As an alternative, Pulse Width Modulated (PWM) techniques, which turn on and off the GTO or IGBT switch more than once per cycle, can be used. This approach allows for simpler transformer topologies at the expense of higher switching losses.

The 6 Pulse STATCOM using fundamental switching will of course produce the 6 N±1 harmonics. There are a variety of methods to decrease the harmonics. These methods include the basic 12 pulse configuration with parallel star / delta transformer connections, a complete elimination of 5^{th} and 7^{th} harmonic current using series connection of star/star and star/delta transformers and a quasi 12 pulse method with a single star-star transformer, and two secondary windings, using control of firing angle to produce a 30° phase shift between the two 6 pulse bridges. This method can be extended to produce a 24 pulse and a 48 pulse STATCOM, thus eliminating harmonics even further. Another possible approach for harmonic cancellation is a multi-level configuration which allows for more than one switching element per level and therefore more than one switching in each bridge arm. The ac voltage derived has a staircase effect, dependent on the number of levels. This staircase voltage can be controlled to eliminate harmonics.

This new technology is expanding rapidly at both transmission and distribution levels (Custom Power) with a variety of applications possible, including reactive voltage support, back to back voltage sourced convertors, similar to back to back HVDC links but with self contained reactive var support, distribution STATCOMs, dynamic voltage restorers, and active filters.

The above description may not have answered all of your critical questions about STATCOMs. You are welcome to take advantage of learning using simulation, with PSCAD/EMTDC and access to the Internet. STATCOM simulator models in full graphics are freely available through the PSCAD Users Group. **See their web site at http://www.ee.umanitoba.ca/~hvdc** . You may also be interested in the upcoming STATCOM course being offered.
Please refer to the following notice.



STATic Synchronous COMpensators : STATCOM

Course and Workshop on Theory, Topologies, Controls and Applications
3 Days
Winnipeg: April 14 - 16 1997

Course Benefits:
This course will enable power systems engineers and distribution planning engineers to effectively understand the application of Static Synchronous Compensators, the various topologies available and the various control alternatives. This knowledge will enhance their personnel skills for system planning, design and operations.

Lectures supplemented with Hands-on Tutorials:
Each participant will utilize PSCAD graphics simulator with the EMTDC electromagnetic transients program in advanced learning workshops. Tutorial cases demonstrating the concepts described in the lectures are prepared. The participant can interact with the PSCAD/EMTDC simulation to reinforce these concepts. Previous knowledge of PSCAD/EMTDC is a benefit but not essential.

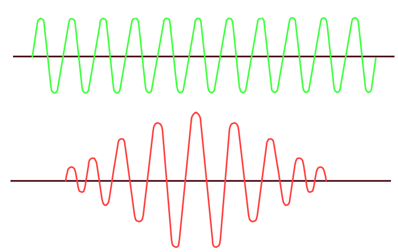
Course Content:

1. Introduction into Static Synchronous Compensators
   - GTO and IGBT Basics
   - Voltage Sourced Convertor Basics
   - Three Phase STATCOM
2. STATCOM Topologies
   - Basic 6/12 Pulse
   - Series 12 Pulse
   - Quasi 12 Pulse
   - Multi-level
3. Controls
   - High Level Control Loops (Q, Voltage, etc.)
   - Firing Controls (PLL Based)
   - PWM Based Controls
   - Control of Harmonics
4. Applications
   - Back to Back STATCOM
   - Active Filtering
   - D- STATCOM
   - Dynamic Voltage Restorer (DVR)

COURSE INSTRUCTORS will be provided from either the Centre or from one of the Centre's sponsors.

Cost : $1000 CDN.

For further Information or reservations, call:
Phone: +1 204 989 1249
Fax : +1 204 453 5074
e-mail: rww@hvdc.ca



Manitoba Hydro HVDC Storm Damage September 5, 1996

At 1:48 am on September 5, 1996 Manitoba Hydro experienced a very critical system event. A very severe weather system ripped through the Nelson River DC Transmission Line corridor damaging a total of 19 ± 500 kV HVDC transmission towers , 18 electrode line wood poles thus reducing Manitoba HVDC capability to zero. At the time of the failures the HVDC was transmitting a total of 2010 MW with 1500 MW export. After the event, the system stabilized with 250 MW import. Amazingly there were no customers lost during the total loss of the HVDC system.

It is very significant that in the face of this serious system event there was very little impact felt by the customers. For most, the morning of September 5 was just like any other morning, with radio and coffee pots on. Manitoba Hydro crews were already being assembled for what would be a major storm repair effort. At one point there were 230 personnel working on the repair.

Manitoba depends on the HVDC system to deliver 75% of the total electricity generated in Manitoba. The Nelson River system is well known to the HVDC community. Briefly described, the Nelson River system consists of 2 HVDC bipoles, or 4 poles with a combined capacity of 3420 MW. There are 2 HVDC 900 km transmission lines located in the same right of way. Each line conductor is rated at 3600 Amps to allow for parallel operation. Originally commissioned in 1985, this paralleling feature proved to be extremely valuable during the period of time required to rebuild the damaged transmission lines.

Fig. 1 Damaged HVDC Tower

The repair crews initially concentrated on establishing one DC transmission line and replacing the electrode line wood poles. Temporary HVDC wood pole structures were installed in 4 ½ days after the storm, restoring the HVDC capability to 75%. Figure 2 shows the temporary wooden pole HVDC line structures utilized. Pole 2 and 4 were operated in parallel, while Pole 1 was operated as a single pole. A transformer outage prior to the storm event prevented Pole 3 from being operated in parallel operation with Pole 1.

Fig. 2 Temporary Wood Pole
+/- 500kV DC

The second HVDC transmission line was reconstructed using spare steel tower and returned to service on September 14, just 9 days after the storm, thus returning the Nelson River system to normal operation. Permanent repairs were performed after the Thankgiving weekend in October. This work including replacing the temporary wood pole structures with new steel towers and reconductoring both transmission lines in order to reduce the number of splices. Again parallel operation of the HVDC system was very significant in reducing the impact of re-constructive work on the transmission lines. The overall availability of the parallel thyristor poles, Pole 1 and Pole 3, was 100% with no forced outages. The availability for the mercury arc pole 2 and thyristor Pole 4 was 88%. Pole 2 experienced 3 arcbacks while in parallel operation.

The overall cost of repairs, loss of export and purchase of energy due to the loss of the DC transmission is estimated at $10 million dollars.

Manitoba Hydro and all of its staff must be congratulated on the outstanding achievement under some very difficult circumstances. They demonstrated how excellent engineering and dedication in design, operation, maintenance, and construction can contribute to reducing the impact of a very serious event. The residents of Manitoba have come to take the supply of electricity for granted and have good reason to be proud of the utility.

PSCAD VERSION 3

Visit The Centre Hospitality Suite
IEEE Winter Meeting In New York

PSCAD-V3 Beta version will be demonstrated in New York at the Centre's Hospitality Suite, located in the New York Hilton & Towers, Suite 4247 in conjunction with the IEEE Winter Power Meeting.

The Hospitality Suite will be open from 5:00 to 8:00 pm Monday February 3 to Wednesday February 5. Demonstrations will be given on both PC and Unix Workstations.

Centre Celebrates 15th Anniversary

On November 4th, 1996 the Centre quietly celebrated its 15th anniversary. The Centre was created in 1981 to utilize the expertise of its sponsors gained through the development of the Nelson River HVDC Transmission System. Over time the Centre has evolved to its present status of international recognition as a "centre" of expertise for HVDC research.

This recognition is due not only to the dedicated efforts of the researchers whose accomplishments include the development of the real time digital simulator technology and PSCAD/EMTDC simulator software, but also the continued support of the sponsor organizations. The Centre Sponsors have maintained their faith in the Centre over the years and throughout the various challenges that were faced. We look forward to continued success in the future.

Achieving Real Time Digital Simulation
November 1989

The Centre Journal is distributed free of charge to any interested party and is posted on our web site http://www.hvdc.ca/

Please direct your inquires to

Manitoba HVDC Research Centre

400-1619 Pembina Highway
Winnipeg , Manitoba
R3T 2G5 CANADA

+1 204 989 1240
Fax +1 204 453 5074
email : journal @ hvdc.ca