A CASE STUDY OF HVDC SUBMARINE INTERCONNECTION BETWEEN TURKEY AND TRNC

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ABSTRACT

HVDC used for electricity transmission before HVAC but it was not as popular in use as HVAC due to the limitations of power electronic technology. In recent years HVDC begin to be more suitable for electricity transmission than HVAC due to many reasons. This paper is mainly a case study of a possible future HVDC interconnection between Turkey and TRNC. For this study SimPower of MATLAB is used to simulate six cases of HVDC interconnection between Turkey and TRNC, three cases for VSC HVDC interconnection and three cases for CSC HVDC interconnection

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I. INTRODUCTION

It's documented fact the first commercial electricity generated (by Thomas Alva Edison) was direct current (DC) electrical power [1] and also the first electrical transmission system was direct current (DC) electrical power in 1882 [1,2], However, DC power at low voltage could not be transmitted over long distances, thus giving rise to high voltage alternating current (AC) electrical systems Nevertheless, with the development of high voltage valves, it was possible to once again transmit DC power at high voltages and over long distances, giving rise to HVDC transmission systems [1].

HVDC technology first made its mark in the early under-sea cable interconnections of Gotland (1954)[3,4] and Sardinia (1967), and then in long distance transmission with the Pacific Intertie (1970) and Nelson River (1973) schemes using mercury-arc valves. A significant milestone occurred in 1972 with the first Back to Back (BB) asynchronous interconnection at Eel River between Quebec and New Brunswick; this installation also marked the introduction of thyristor valves to the technology and replaced the earlier mercury-arc valves [5].

It has been proved that HVDC system is a practical solution when HVAC transmission is not possible in the case of that underwater cables are used [6]. The safe operation of HVDC system plays an important role for the stability of power system [7]. This study is mainly concerned about submarine interconnection between Turkey and TRNC, Certainly this study is also suitable or it can be modified to be suitable for another submarine interconnection or even any HVDC interconnection, It give an accurate results by making use of Simpower simulation which is a part of Matlab program since Simpower is using real models and though this study can be a basis for a future project for submarine interconnection between Turkey and TRNC.

The analysis and simulation was not realized before and this paper is the first of its kind for specific case of connection of Turkey-TRNC sub sea interconnection. The system is assumed to be bidirectional system.

The simulation results proved that VSC HVDC interconnection is a better solution for such an application although it is more CSC HVDC interconnection but the system stability with VSC HVDC interconnection worth that difference in cost.

In the world most of the countries adopted for 230 kV transmission voltages, in Europe also 230 kV transmission is adopted for many countries as there should be a standardization in coming future [2] Turkey has to adopt for 230 kV and in this paper the simulation is are done for 230 kV transmission voltage

II. VSC INTERCONNECTION

The first HVDC system based on IGBT VSCs was commissioned in Sweden in 1997 [8], after that several VSC-HVDC projects have been commissioning in the world. They are mainly used in the supplying power to islands, transmission for wind power, and controlled asynchronous [9,10]

The increasing rating and improved performance of self-commutated semiconductor devices have made possible High Voltage DC (HVDC) transmission based on Voltage-Sourced Converter (VSC). Two technologies offered by the manufacturers are the HVDC Light and the HVDC Plus [11]. The principal characteristic of VSC-HVDC transmission is its ability to independently control the reactive and real power flow at each of the AC systems.

VSC INTERCONNECTION WITH LOAD

The main VCS which is used in this study is shown in Figure 1, starting from the left side there is Turkey side source which is 230 kV, 300 MVA and its connected to the rectifier which is next to it after that is the transmission cables which is 90 km long and is connected to the inverter station which is connected to the load and TRNC source which is 230 kV, 260 MVA. The main component of the rectifier station and inverter station is the three-level bridge IGBT/Diodes.

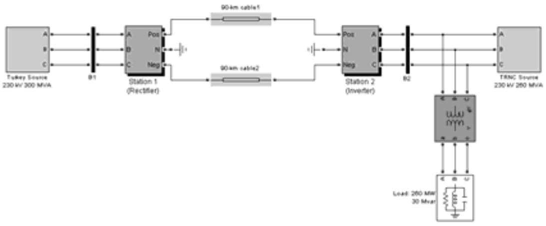

Figure 1. VSC-Based HVDC Transmission Link with load

After simulating this VSC the voltage and current of the cables at the sending and receiving sides is obtained (cable one graphs is shown in Figure 2) where the voltage is scaled to pu (1 kV= 1 pu) and the current is scaled to pu (1 kA= 10 pu) also all the following cases will be scaled to the same value for voltage and current we notice that the system reach steady state after one second and after that the system run steadily without any problem, the graph of the load voltage is obtained and it is shown in Figure 3, for the load voltage it reach the steady state at the time with power transmitted from Turkey side.

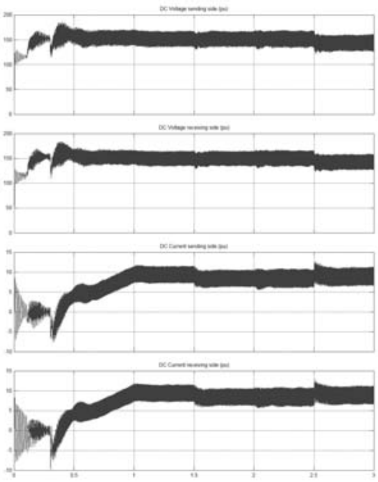

Figure 2. Cable one voltage and current at the sending and receiving side of VSC-Based HVDC Transmission Link with load

VSC INTERCONNECTION WITH LOAD AND A FAULT

In this case the same configuration is applied but in addition a timed fault is applied to the load (as it can be seen in Figure 5) in order to see how the system work when there is an actual fault applied to it and can the system restore itself and go back to normal operation after the fault is over or not.

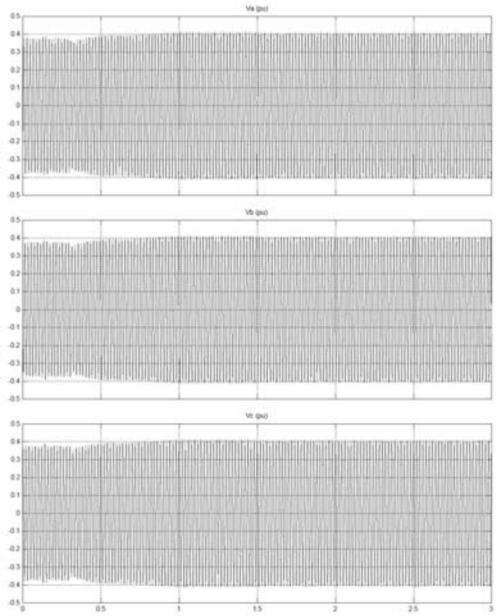

Figure 3. Load voltage of VSC-Based HVDC Transmission Link

There are three faults applied to each phase individually as it can be seen from Figure 4 the faults are applied at a different times each is .05 seconds long as following , phase A at 1.7-1.75 s, phase B 1.8-1.85, phase C 1.9-1.95. the graphs of cable one current and voltage at sending and receiving sides are shown in Figure 5, as it can be observed from the Figures of the cable that it is affected directly by the faults which is applied to the load but after the three faults period is over the power transmission is resumed and that show that the system can be recovered by itself after the transmission system is endangered by faults which can occur during normal operation, the most important that for the system to be able to recover from those faults.

Also the graphs for load voltage is obtained and it is shown in Figure 6, as it can be seen from Figures the effect of the fault is obvious in each phase individually and each phase is effected by the fault on the other phases

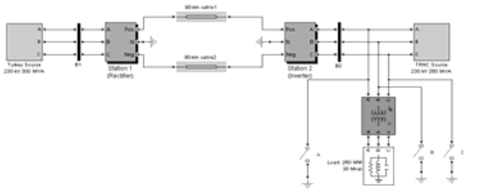

Figure 4. VSC- Transmission Link with load and fault

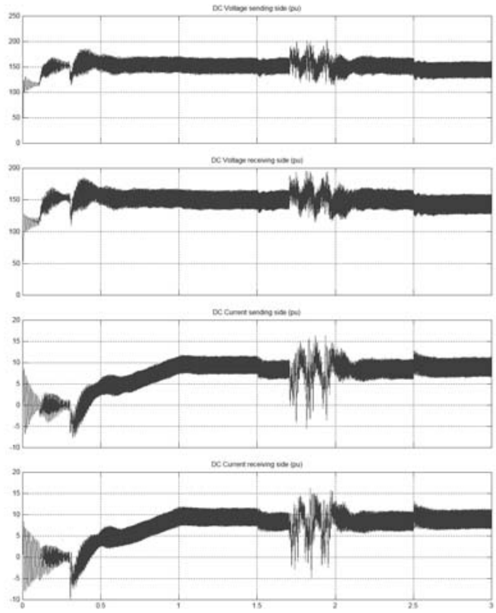

Figure 5. Cable one voltage and current at the sending and receiving side of VSC-Based HVDC Transmission Link with load after applying a fault

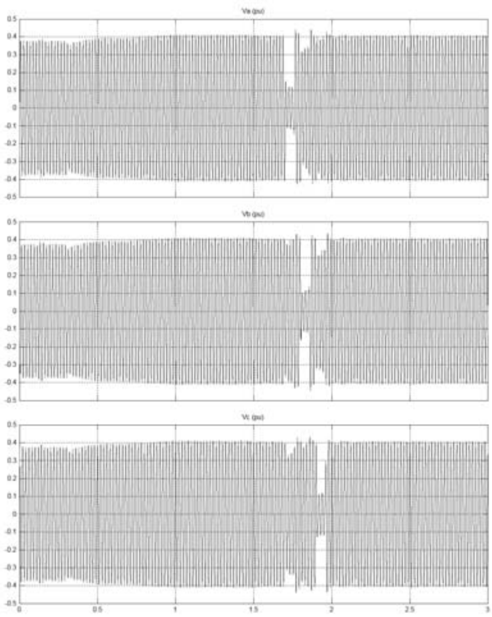

Figure 6. Load voltage of VSC-Based HVDC Transmission Link after applying a fault to it

VSC INTERCONNECTION WITHOUT TRNC SOURCE

In this case TRNC source is removed to see if generator in TRNC is shutdown for a time or can those generators be removed completely in the future and depend on Turkey source only, can the system feed the load without any source in TRNC side.

As it can be seen in Figure 7 the TRNC sources is completely removed from the system and the only available source is in Turkey in one side of transmission system.

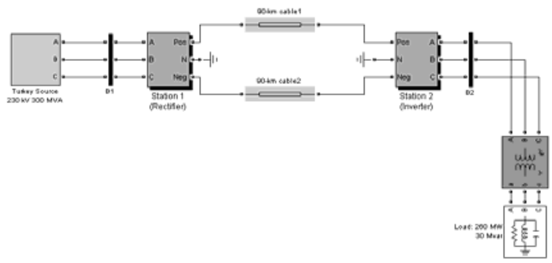

Figure 7. VSC-Based HVDC Transmission Link with one source only

The simulation is run and again the voltage and current for cable one is obtained and is shown in Figure 8, also graph of the voltage of the load is obtained and it is shown in Figure 9.

From the cable one graphs, we can see that the transmission from Turkey side to TRNC is decreased but still there is power transmission from the Turkey

Also we can observe from the load voltage graphs in Figure 9 that the energy is transmitted from turkey side to the load although there is no source at all in the TRNC at all, Certainly there is a decrease in the amount of voltage value since the sources of the TRNC is absent at all and the amount of the power transmitted from turkey side is decreased.

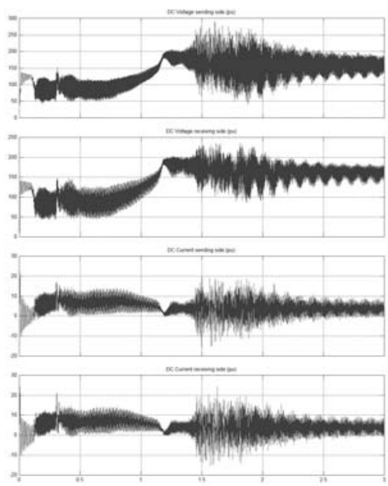

Figure 8. Cable one voltage and current at the sending and receiving side with Turkey source only

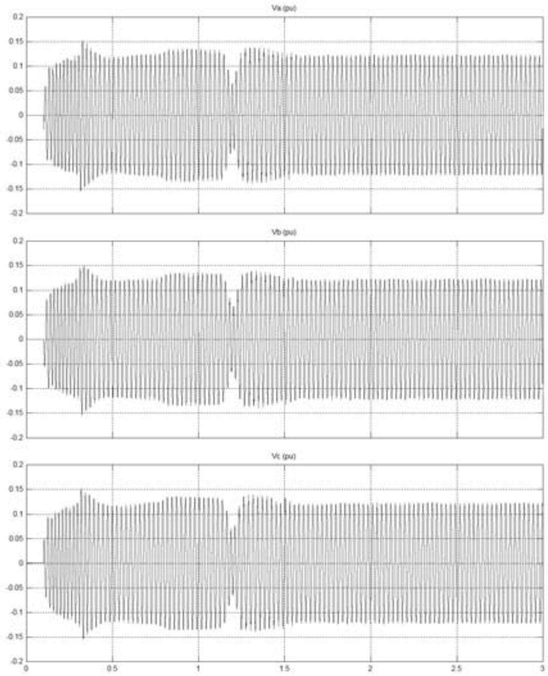

Figure 9. Load voltage of VSC-Based HVDC Transmission Link with Turkey source only

III. CSC interconnection

A current sourced converter is characterized by the fact that the dc current flow is always in one direction and the power flow reverses with the reversal of dc voltage, the current source converter studied here uses thyristors as the switching on devices.

The HVDC technology which based on thyristor valve has been developed since 1970s [12]

CSC-BASED HVDC TRANSMISSION LINK WITH LOAD

In this case CSC with load (Figure 10) is considered the sources are the same as the cases with VSC, also the load is the same.

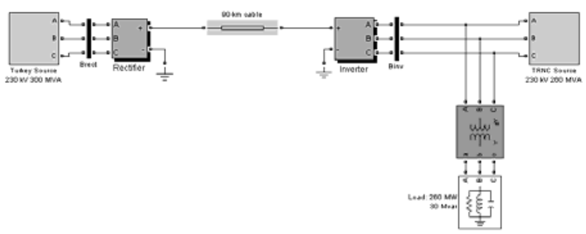

Figure 10. CSC-Based HVDC Transmission Link with load

Now the CSC is simulated and the graph of the cable voltage and current at the receiving side and at the sending side is obtained and it is shown in Figure 12, the graph of the load voltage is not shown since it is similar to the VSC case.

As it can be observed from the graphs of the cable at both sides receiving and sending sides, the transformation of power from AC to DC is working ok without any problem and the steady state is reached after 1.2 s.

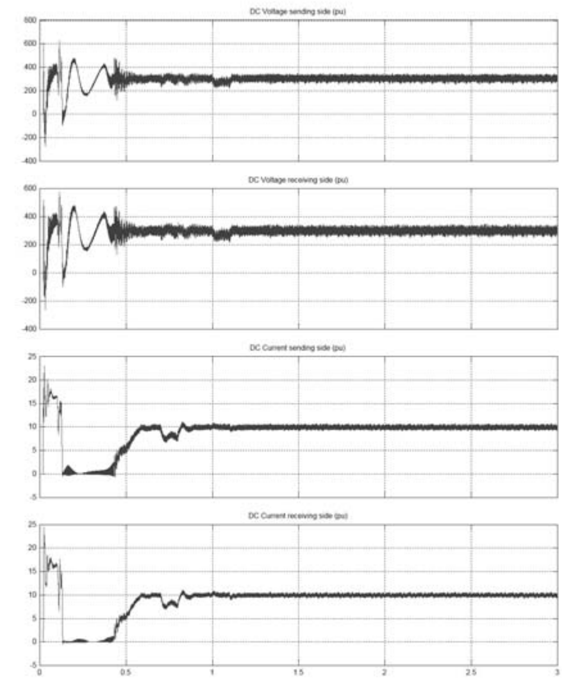

Figure 10. Cable voltage and current at the sending and receiving side of CSC-Based HVDC Transmission Link with load

CSC-BASED HVDC TRANSMISSION LINK WITH LOAD AND A FAULT

Now a fault applied to the load in the previous case to see how the CSC can deal with this fault, can it recover or not after the fault is over, the CSC with a fault is shown in Figure 11.

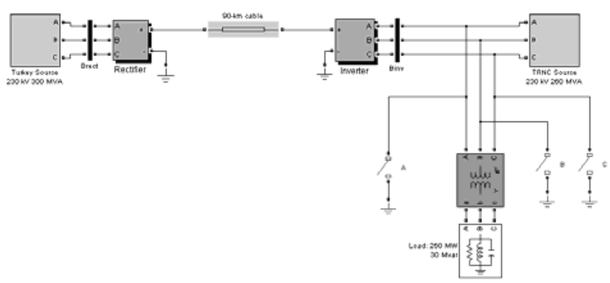

Figure 10. CSC-Based HVDC Transmission Link with load and a fault

There are three faults applied to each phase individually as it can be seen from Figure 11 (the same way as with VSC) the faults are applied at a different times each is .05

seconds long as following , phase A at 1.7-1.75 s, phase B at 1.8-1.85, phase C at 1.9-1.95.

Now the CSC is simulated and the graph of the cable current and voltage is obtained at the sending side and at the receiving side and they are shown in Figure 11, the graph of the load voltage is similar to the one with VSC with fault.

As it can be observed from the graph of the cable voltage and current at the sending side and receiving side, the transmission from AC to DC is effected directly but after the fault is over the transmission from AC to DC is resumed just as with case of VSC with fault applied to the load.

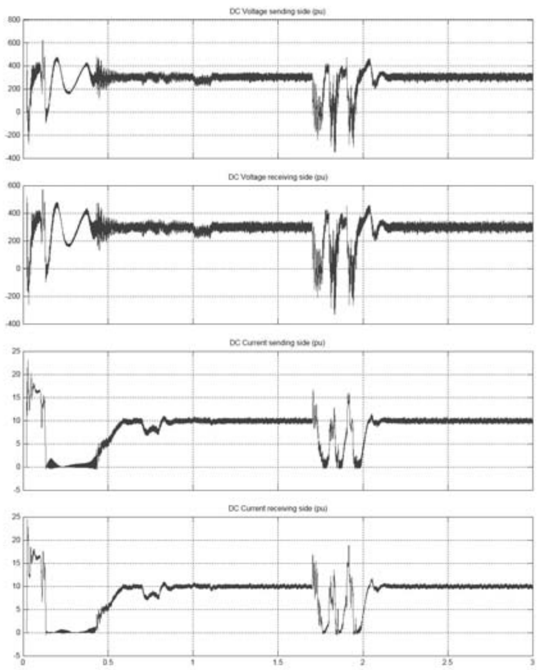

Figure 11. Cable voltage and current at the sending and receiving side of CSC-Based HVDC Transmission Link with load after applying a fault

CSC INTERCONNECTION WITHOUT TRNC SOURCE

In this case TRNC source is removed as it was done with VSC to see if generator in TRNC is shutdown for a time or can those generators be removed completely in the future and depend on Turkey source only can the system feed the load without any source in TRNC side.

As it can be seen in Figure 12 the TRNC source is completely removed from the system and the only available source is in Turkey in one side of the link.

the graph and again voltage and current of the cable at the sending side and at the receiving side is obtained and it is shown in Figure 13 , also the graph of the load voltage is obtained and it is shown in Figure 14.

As it can be observed from the graph of the voltage and current of the cable there is no transmission from AC to DC, also there no voltage at the load at all.

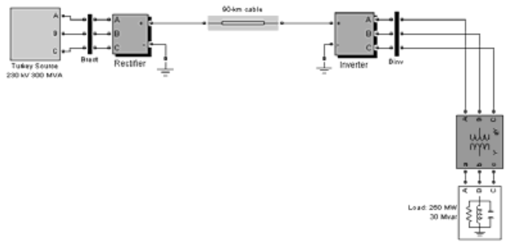

Figure 12. VSC-Based HVDC Transmission Link with one source only

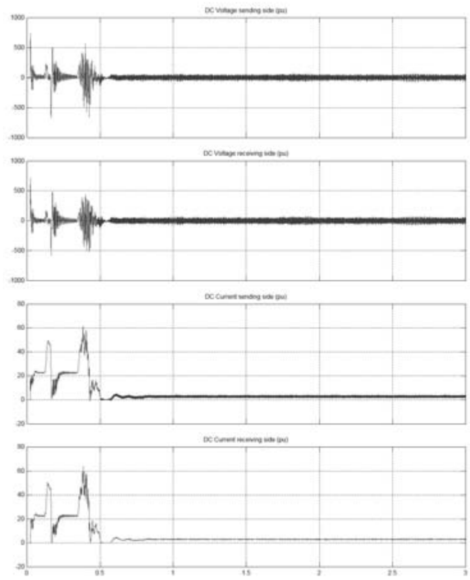

Figure 13. Cable voltage and current at the sending and receiving side with Turkey source only

Figure 14. Load voltage of CSC-Based HVDC Transmission Link with Turkey source only(Zero voltage)

IV. DISCUSSION AND CONCLUSION

HVDC can't be counted as new technology since it was in use before HVAC, but due to the fact that the power is generated as AC and it was difficult to convert it to DC or back to AC due to the limitation of the converter technology at that time.

With advance of technology of power electronic, the use of HVDC transmission increased and it continue increasing with more and more advance in power electronic devices to replace current AC transmission lines or for new transmission lines, since it is more economical for long distance transmission than AC, also it does not cause health problems as AC.

In this study six cases of HVDC interconnection were tested, three cases for VSC and three cases for CSC. The three cases for VSC were as following, first one is the VSC transmission interconnection from Turkey to TRNC with a load in order to test the transmission from AC to DC without a fault, in this case we have a steady transmission from AC to DC , in the second a three successive timed fault is applied to the load to see if the system can recover after those fault is over or not, the graphs shows that the transmission from AC to DC is affected directly by those faults but after the faults is over the power transmission returned to its original state, also the voltage at the load and this shows the ability of the system to recover after it endangered to a real fault, for the third case the TRNC source is removed from the system to see if we can feed the load from Turkey source only without any source at TRNC side at all, the simulation result show that transmission of power decreased but it was able to feed the load and this very important point, it shows that the load in TRNC side can depend completely in the power transmitted from turkey which is more stable than the power generated in TRNC side. In CSC cases, the first two cases the same parameters is applied as with VSC first two cases and a similar result is obtained. In the third case also the same thing is done, the TRNC source is removed completely but here we don't have the same result as with VSC, the transmission of power from AC to DC is stopped completely.

The main idea for doing this analysis was to test a possible application of HVDC subsea connection between Turkey and TRNC. The parameters for suggested possible application were used and modeled by MATLAB SimPower. The simulation result proved that VSC is a better solution for such an application.

This paper is done as case analysis for the authorities to be a reference for a future possible realization of HVDC subsea interconnection.

Such an analysis and simulation was not realized before and this paper is the first of its kind for the specific case of connection of Turkey-TRNC subsea interconnection, the system is assumed to be a bidirectional system.

V. FUTURE WORK

This paper proved that for the specific Turkey-TRNC interconnection VSC is the best solution.
A more detailed structure study with VSC can be done in future for the real TRNC distribution system to get information about the operation with complete distribution system.

REFERENCES

1. R. Rudervall, J.P. Charpentier, R. Sharma, "High voltage Direct current (HVDC) Transmission Systems Technology review Paper" , *ABB power Systems* .
2. K. W. Kanngiesser, H. Huang, H. Lips, *HVDC systems and their planning*, Siemens, 2005.
3. C. Zhao, H. Cui, G. Li, "A Novel HVDC Transmission System with Parallel Large Capacitor Connected in the DC Side of the Rectifier and Its Technical Feasibility", *IEEE*, 2005.
4. G. Li, G. Li, H. Liang, M. Yin, C. Zhao, "Operational Mechanism and Characteristic Analysis of Novel Hybrid HVDC system", *IEEE*, Oct 2006.
5. V. K. Sood, *HVDC and FACTS Controllers*, KLUWER ACADEMIC PUBLISHER, 2004.
6. C. Weihua, J. Quanyuan, C. Yijia, "Risk based vulnerability assessment for HVDC transmission system", *IEEE*, Nov 2005.
7. X. Wenhao, L. Zhiwei, H. Shaoxian,W. Gang, "A Model of HVDC Control System Based on Hybrid Petri Net", *IEEE*, 2005.
8. N. Stretch, M. Kazerani, R. El Shatshat, "A Current-Sourced Converter-Based HVDC Light Transmission System", *IEEE*, Jul. 2006.
9. G. Li, G.. Li, H. Liang, C. Zhao, M. Yin, "Research on Dynamic Characteristics of VSC-HVDC System", *IEEE*, Oct 2006.
10. Gu Li, Gengyin Li, C. Zhao, H. Liang, Ming Yin, "Research on Dynamic Mathematic Model of VSC-HVDC Based on Energy Conservation Principle", *IEEE*, 2005.
11. Z. Chao, Z. Xiaoxin, L. Ruomei, "Dynamic Modeling and Transient Simulation for VSC based HVDC in Multi-Machine System", *IEEE*, Oct 2006.
12. G. Jie Li, T. T. Lie, Y..Zhang Sun, S. Ye Ruan, L. Peng, X. Li, "Applications of VSC-Based HVDC in Power System Stability Enhancement", *IEEE*, Nov. 2005.