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RTDS를 이용한 제주도 전력계통에서의 전압형과 전류형 직류송전 시스템 특성분석

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Characteristic analysis of LCC and VSC HVDC system in Jeju power system using RTDS

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Abstract - This paper performs a comparison analysis of two types of HVDC system in Jeju power system. A traditional HVDC transmission system had been composed of line commutated converter based on thyristors and the development of semiconductors enables to apply voltage source converter using IGBTs. The detailed parameters of Jeju power system were considered to make a similar condition with real system in real time digital simulator. Two types of HVDC transmission system were modeled and simulated to compare their characteristics in Jeju power system. The simulation results demonstrate that the VSC-HVDC system has more stable performance due to the fast response speed than LCC-HVDC when the transmission capacity was fluctuated.

1. Introduction

Since the first commercial HVDC system was constructed by ABB between the mainland of Sweden and Gotland, more then 50 projects of HVDC system have been completed in the world. Korea Electrical Power Corporation installed a HVDC system using submarine 100 km DC cable from Haenam S/S to Jeju S/S in 1998.

A traditional HVDC transmission system had been composed of line commutated converter (LCC) based on thyristors [1]. With the development of semiconductors and control equipments, HVDC transmission with voltage source converter (VSC) based on IGBTs is possible to be serviced commercially [2].

Jeju island became known as the suitable place for wind power generation system in Korea. As a wind power has been concerned as one of the major renewable energy resources, the installation of wind turbine has been increased rapidly. However, the week electrical power utility of Jeju island limits installation of wind power generation system due to grid instability by fluctuation of wind power. A HVDC system is indicated as the method by converting AC to DC to solve this problem [3].

In this paper, the two types of HVDC system were simulated and analyzed using real time digital simulator (RTDS). LCC-HVDC and VSC-HVDC systems were designed to connect wind power generation system and Jeju utility. The detailed parameters of Jeju power system were applied to the modeled Jeju power utility in RTDS to make the actual grid condition for a simulation of HVDC system. Transmission capacity of HVDC system is changed from 60 MW to 30 MW to verify the response characteristics of VSC-HVDC and LCC-HVDC. The simulation results demonstrate that the VSC-HVDC system is proper in Jeju power system with wind turbines. The VSC-HVDC system can transmit electrical power with fast response time than LCC-HVDC when the transmission capacity is fluctuated.

2. Characteristics of LCC and VSC HVDC system

There are two kinds of conversion system for HVDC transmission. The first one is LCC-HVDC using thyristors. The major merit of LCC-HVDC is that it can be operated with high current due to a high current capacity of thyristor. Additionally LCC-HVDC has a long life span and high operational reliability. LCC based HVDC transmission has a reliable track record of over three decades and currently the largest installed LCC-HVDC system is the 6300 MW ±600 kV Itaipu link in Brazil [4]. However, LCC-HVDC needs an extra reactive power compensator due to consumption of reactive power from LCC.

The other is VSC-HVDC using IGBTs. IGBT converter can connect a wind power generation system which causes a fluctuation of frequency of grid with a weak AC grid because it can control active and reactive power independently. A VSC-HVDC system doesn't need extra grid stabilizer by controlling of reactive power. Also, the VSC-HVDC system is easier to design and more compact than the LCC. Differences between LCC and VSC HVDC system are presented in Table 1 [5].

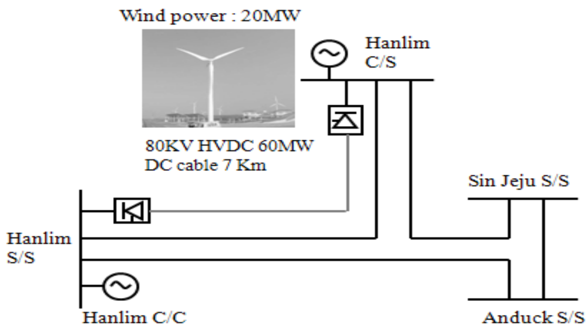
<Table 1> Comparison of LCC and VSC HVDC system

Aspect	LCC	VSC
Power electronic device	Thyristor	IGBT
Convertor cost	Cheap	Expensive
Power losses	Small	Big
Control of reactive power	Normal	Small
Operation with passive AC network	Bad	Good
Land usage	Bad	Good
Long-distance transmission	Possible	Impossible

3. Design of HVDC system

3.1 Jeju power system

The power system of Hanlim area in Jeju island is modeled with detailed properties in RTDS. The designed system includes three 154 kV substations, three gas turbine generators and a wind farm. The modeled three generators has 135 MW power capacity and are placed in Hanlim C/C. Each HVDC system connects Hanlim C/S with Hanlim S/S and 120 MW load is connected to the Sinjeju and Andduck S/S. Fig. 1 shows the modeled Jeju power utility including HVDC transmission system in RTDS. The specifications of medeled Jeju power system are presented in Table 2.



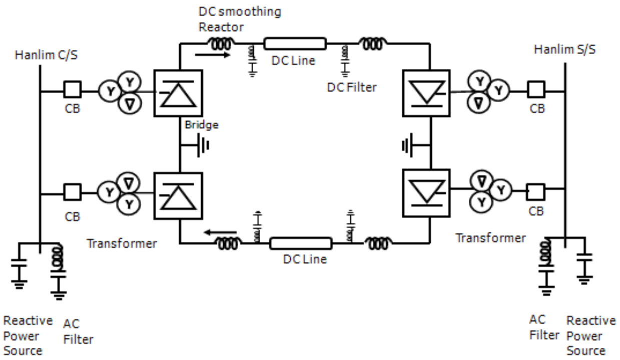
<Fig. 1> Modeled Jeju power system

<Table 2> Specifications of modeled Jeju power system

Hanlim HVDC		AC network	
DC voltage	80 kV	Gas turbine #1	45 MW(Hanlim S/S)
DC current	750 A	Gas turbine #2	45 MW(Hanlim S/S)
Main transformer	154/34.2 kV 60 MVA	Steam turbine #1	45 MW(Hanlim S/S)
X_c	0.12	Wind farm	20 MW(Hanlim C/S)

3.2 LCC-HVDC system in Jeju

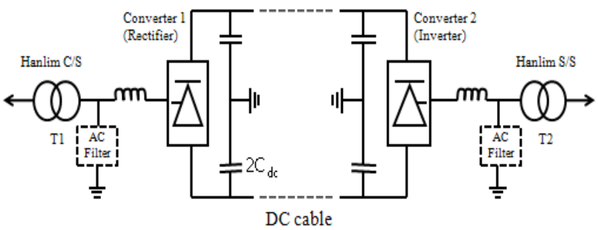
Fig. 2 displays the circuit diagram of LCC-HVDC system. A bipolar classic HVDC system consists of AC filters, shunt capacitor bank or other reactive-compensation equipment, transformer, thyristor converters, DC reactors, DC filters, and DC cables. The DC-link voltage is 80 kV and the current is 750 A. Transmission capacity is 60 MW. LCC-HVDC system is controlled with firing angle. The normal HVDC control structure is power control in the rectifier and extinction angle control in the inverter.



<Fig. 2> Circuit diagram of LCC-HVDC

3.3 VSC-HVDC system in Jeju

Fig. 3 presents the circuit diagram of VSC-HVDC system. A typical VSC-HVDC system consists of AC filters, transformers, IGBT converters, phase reactors, DC capacitors and DC cables. The DC-link voltage is 80 kV and the current is 750 A. Transmission capacity is 60 MW. The VSC output is determined electronically by control of high frequency, kHz range pulse width modulation (PWM). The control of PWM makes it possible to create any phase angle or amplitude within ratings.

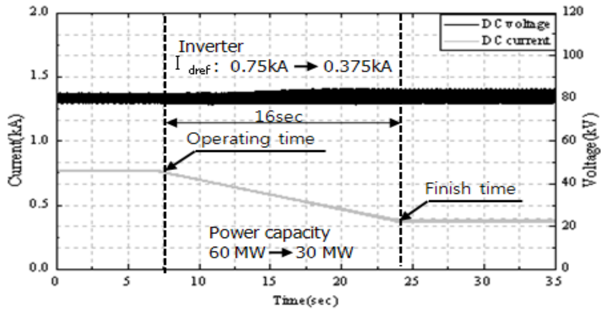


<Fig. 3> Circuit diagram of VSC-HVDC

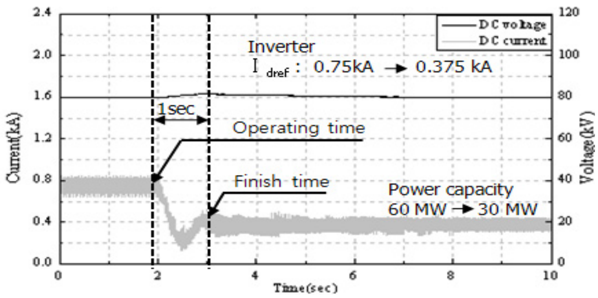
4. Simulation and the results

The two kinds of HVDC system explained in previous section were designed by RTDS. The rectifier of HVDC system was connected with Hanlim C/S which includes wind power generation systems and the inverter of HVDC system was connected with Jeju power system. The modelled HVDC systems were simulated to observe their response time when the transmission capacity through the HVDC was changed from 60 MW to 30 MW.

Fig. 4 and Fig. 5 present the DC current and voltage of LCC-HVDC and VSC-HVDC, respectively, when the transmission capacity was changed from 60 MW to 30 MW. It takes about 16 seconds to decrease the transmission capacity in case of the LCC-HVDC as shown in Fig. 4. On the other hand, the VSC-HVDC system takes about 1 second to reach the changed capacity as given in Fig. 5. According to the simulations results, the rapid speed of the VSC-HVDC system improves power stability and quality through control of active and reactive power.



<Fig. 4> The current and voltage of LCC-HVDC



<Fig. 5> The current and voltage of VSC-HVDC

5. Conclusions

In this paper, LCC and VSC type of HVDC transmission systems in Jeju power system are modeled and simulated to compare their performance with the variation of wind power. The simulation results present that the VSC-HVDC system tracked changed power capacity within 1 second and LCC-HVDC system tracked within 16 seconds when the power capacity of HVDC system is dropped from 60 MW to 30 MW. Therefore, it is verified that the VSC-HVDC system has more stable performance due to its fast response speed with the variation of wind power than LCC-HVDC system. A comparison study between two types of HVDC system with real wind speed data will be progressed to analyze their efficiency under actual condition in the near future.

[Acknowledgment]

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