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KAPES
KEPCO and Grid Solutions Joint Venture

Study Committee B4

DC SYSTEM AND POWER ELECTRONICS

Paper ID_10246

Study on the Converter Valve Peak Voltage of Bukdangjin-Godeok HVDC Stystem under Various Operating Condition

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Motivation

- HVDC transmission lines play an importatnt role along with the increase in renewable energy generation for stations located in remote areas
- Repetitive voltage stresses are inevitable due to the switching activities of Thyristor converter valves in an LCC HVDC system
- Thyritor valves shall be designed considering voltage stresses during operation
- Studies influencing factors on the vlave peak voltages and commutation overshoot under various system operating conditions
- Discusses how the converter valves can be protected from the transient voltage stresses

Method/Approach

- Two voltage stresses, CCOV and PCOV, defined in IEC 60071-5 were studied using varios operation conditions of 3GW, ±500kV Bukdangjin - Godeok (South Korea) HVDC transmission link
- Voltage stresses were simulated by EMTDC sofrware
- Examine the transient overshoot voltae during valve off-state with varying stray capacitances of transformer
- Investigate vlave voltage waveform with different firing angles and load condtions of the system

Bukdangjin-Godeok transimission link

- Pole 1 link has been in service since 2020 and Pole 2 link is currently under construction

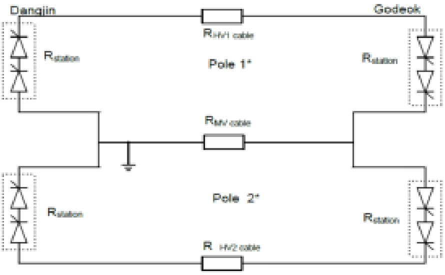

Figure 1 Simple diagram of Bukdangjin transmission link

Definition of CCOV and PCOV

- Valve experiences voltage stresses during its off-state
- CCOV : Crest Continuous Operating Voltage
- PCOV : Peak Continuous Operating Voltage
- CCOV and PCOV are key factors for the insulation coordination design of the converter station

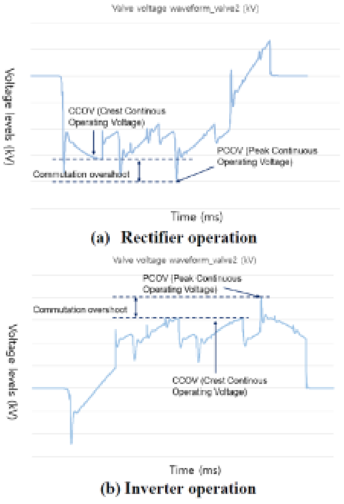

Figure 2 Operating voltage of a valve arrester

Influencing factor to valve transient voltage

- The characteristics at individual Thyristor valves
- The recovered charge characteristics betweem series-connected Thyristor levels
- Damping circuit elements in Thyristor levels
- The operation conditions (firing angle and the valve commutation voltages)

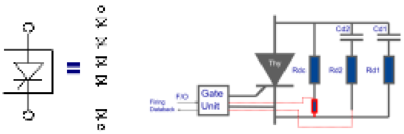

Figure 3 Diagram of Thyristor level

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Study with stray capacitance of converter transformer

- Valve transient overshoot voltages have been studied with the following four parameters

– Transformer series capacitance (C_{vw_s})

– Transformer shunt capacitance (C_{vw_sh})

– Transformer winding end capacitance (C_{w_e})

– Transformer bushing capacitance (C_{b_w})

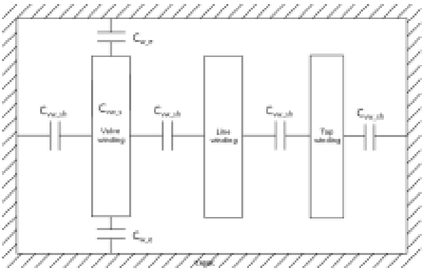

Figure 4 Simple model of converter transformer capacitance

- The specific spot in the valve voltage waveform was examined during valve off-state which is the lowest and the most severe voltage level
- The larger stray capacitances (C_{vw_sh} and C_{b_w}) causes the greater PCOV level

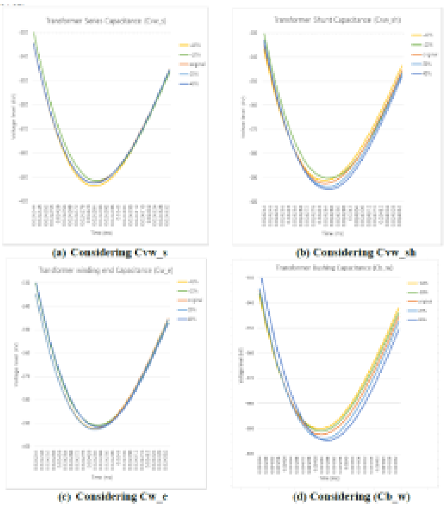

Figure 5 The effect that varying transformer stray capacitance has on valve transient voltage

Study with operating conditions with different firing angles

- Investigated overvoltage properties with three different firing anlges : 15°, 18° and 25°
- The larger firing angle causes the larger amplitude of commutation overshoot and PCOV level
- However, the increasing firing angle does not influence the CCOV level signigicantly

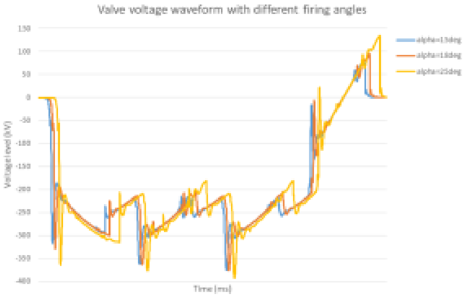

Figure 6 Valve voltage waveform with different firing angles

Study with operating conditions with different load condition

- Investigated overvoltage properties under four different load conditions (firing angle) : 100%(25°), 80% (36°), 60% (44°) and 40% (55°)
- The point of largest PCOV level in the voltage waveform was changed depending on the load condition
- Therefore, the most onerous voltage level shall be studied through simulation under various HVDC system operating conditions

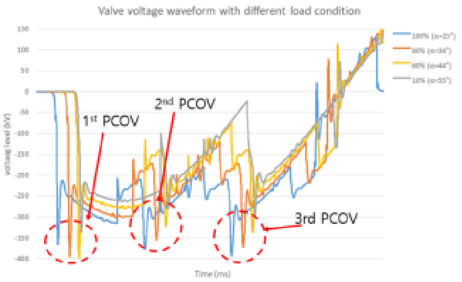

Figure 7 Valve voltage waveform with different load condition

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Overvoltage protection 1 : Valve Surge arrester

- In case the applied voltage exceeds the protective level of surge arrester, it starts to conduct current to protect the associated equipment from the exceeded voltage
- The protective level of the valve surge arrester is determined by CCOV, PCOV and impulse voltages.

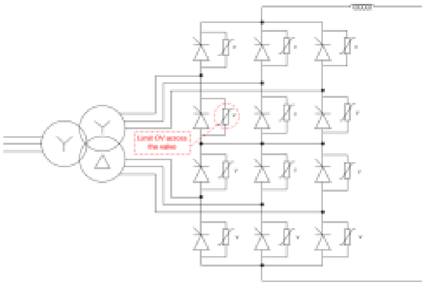

Figure 8 Location of valve surge arresters

Overvoltage protection 2 : Protective firing of thyristor

- VBO (Break-over voltage) protection level is set by the controls system
- Setting the VBO level provides the main over voltage protection in the forward direction

The number of thyristor levels in a valve

- The number of thyristor level for a valve is determined by the surge arrester protective level (noramlally SIPL is uesd)
- The minimum required number of thyristor levels can be calculated :

$$N_{levs} = SIPL \times K_1 \times K_2 / U_{RSM}$$

Where:

SIPL : the valve arrester's Switching Impulse Protective Level

U_{RSM} : the Thyristor non-repetitive reverse voltage capability

K_1 : the factor defined by SIWL / SIPL (1.15 or 1.2)

K_2 : the voltage sharing factor for switching impulse

Performance of damping capacitor

- Damping capacitance shall be selected big enough to damp the transient voltage and its dv/dt
- The peak transient voltage observed when the firing angle is 90deg
- Commutation overshoot : Damping capacitance doesn't affect the overshoot voltage significantly

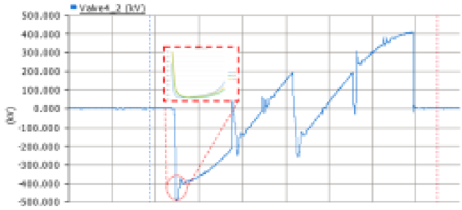

Figure 9 Examined transient overshoot voltage at α=90°

- Valve losses : the larger capacitance produces the more power losses for P_{v5} and P_{v6} and there is no difference in other losses

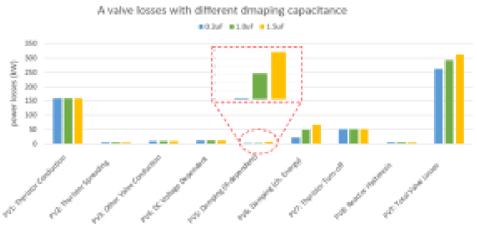

Figure 10 Valve losses with different damping capacitance

Conclusion

- The larger stray capacitance cause the larger transient overshoot during valve off-state
- To limit the overvoltage, surge arrester and protective firing shall be considered in the converter station as a protection scheme
- The larger capacitance of damping capacitor in Thyristor levels reduces voltage overshoot but increases power losses during operation
- Enhanced the understanding of an LCC HVDC system design process regarding voltage stresses of converter valves
- Contributed to guide the design of the thyrisotr valve in an LCC HVDC system

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