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Research Article

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Diagnosis of Commutation Failure in HVDC Transmission System Using Matlab

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Abstract:

Commutation failure problem is normal in hvdc system .In this paper we study how we mitigate the problem of commutation failure .Fast diagnosis of commutation failure in HVDC systems can improve the level of operation in the power systems.. The abc-αβ transformation is used for three-phase fault detection, and the zero-sequence voltage, is used for single phase fault detection. when ac faults occurs control system operate very quickly because both detection methods are based on the instantaneous values.Fast diagnosis of commutation failurein HVDC systems can improve the level of operation in the power systems. An additional angle is deducted from the firing order at the inverter station after detecting the fault , that increase the commutation margin .By this method we effetely reduce the commutation failure risk.

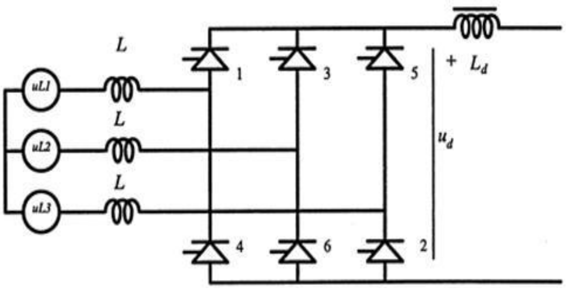
Index Terms: Commutation failures, voltage dips, power system faults, HVDC transmission

I. INTRODUCTION

Commutation failure are very common dynamic events in high voltage dc (HVDC) transmission systems . Failure to complete commutation before the commutating voltage reverses is referred as commutation failures. Commutation failures occur in HVDC systems due to ac voltage dips (possibly caused by an ac systems shortcircuit), increased direct current, late ignition or a combination of these. The inverter is more prone to commutation failure. The sensitivity of an HVDC inverter to commutation failures depends on the specific main circuit design and on the control system. It is reported that commutation failures may happen during an ac system disturbance, where the voltage reduction is only as small as 10% and due to this overlapping angle increases. Over current flow in valve due to repeated commutation failure and after clearing of fault ,it delay the restart time .Sometime blocking of valve takes place. Commutation failures happen if the commutation of current from one valve to another has not been completed before the commutating voltage reverses across the ongoing valve. This results in a short circuit across the valve group. The basic reason for commutation failures is that the extinction angle during system disturbance is too small. If we enlarge the commutation margin we can mitigate commutation failure.

II. BASIC WORKING PRINCIPLE

The basic configuration of an HVDC converter is the three-phase, full-wave bridge circuit shown in Fig. 1. The circuit is known as Graetz Bridge which is universally used because it provides better utilization of the converter transformer and a lower voltage when valve is in off state.



.Fig. 1. Equivalent circuit for three-phase full-wave bridge converter

By using Graetz Bridge power can flow in both directions that is from rectifier to inverter and vice versa. By applying different firing angles to the valves are provided we can reverse the power flow. When the firing angle is less than 90 degrees ,converter act as rectifier , so that power flows from the ac side to the dc side; When the firing angle is greater than 90 degrees, converter act as a inverter mode so that the power flows from the dc side to the ac side. Because of finite leakage inductance in converter transformer (protect the valves during valve short circuit) commutation from one valve to another valve is not instantaneous.During commutation, three valves will be conducting. Such a period is called overlapping period which is normally less than 60 degrees.

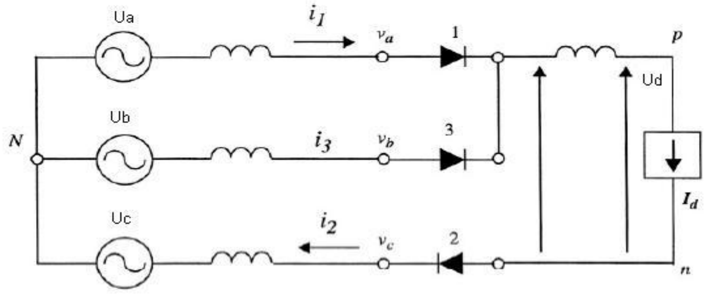


Fig 2 converter bridge circuit with valves 1,2 and 3

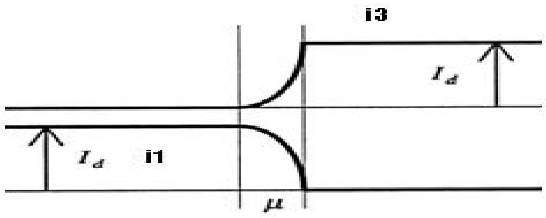


Fig.3 commutation of current in valve 1 and 3

If suppose the valve 1 and valve 2 is conducting at an instant (figure 2), and valve 3 is fired and starts conducting. But still valve 1 is conducting until the stored magnetic energy in the converter transformer goes to zero. During the commutation Id is summation of i1 and i3, i1 is decreasing from Id to zero and i3 is increasing from 0 to Id (figure 3).Voltage drop due to overlapping angle can be achieved by fig4

$\Delta Ud = 6.f.L.Id = 6.(\omega/2\,\Pi),L.Id$ (1)

$\Delta Ud = 3.(\omega./\Pi).L.Id$ (2)

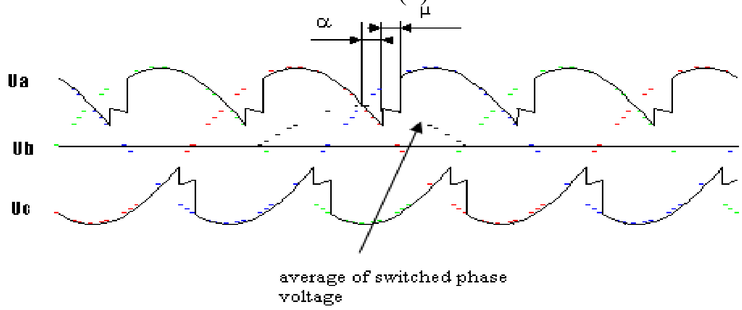


Fig.4 direct voltage with effect of delay angle and overlapping angle

Since the current changes through the inductance is 6 times for 6-pulse converter

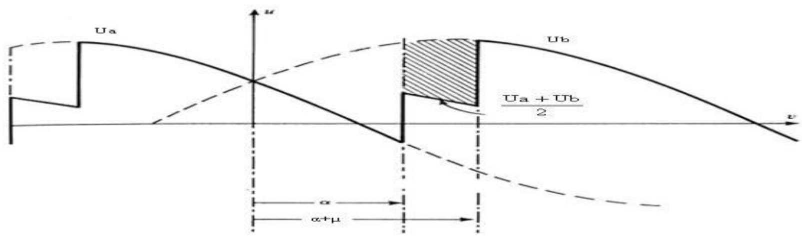


Fig. 5 rectifier direct voltage

Therefore, the total rectifier DC voltage will be

$Ud = 1.35.Ull.\cos\alpha - (3/\Pi).\omega.L.Id$ (3)

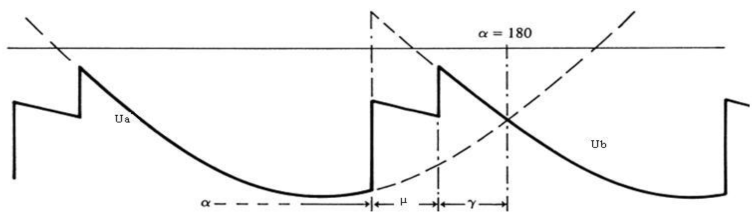


Fig.6 Inverter direct voltage

The inverter DC voltage will be found by
$Ud=1.35.ULL.\cos\gamma-(3/\Pi).\omega.L.Id$(4)

III. COMMUTATION FAILURE

Commutation failures in HVDC systems are mainly caused by voltage dips due to ac system faults .voltage dips may cause both voltage magnitude reduction and phase-angle shift. Voltage dips may affect the commutation in following way-

1) Voltage magnitude reduction

when there is a voltage dip commutating ac line-to-line voltage decreases, as shown in Fig.7 . Since the voltage magnitude has decreased, here the commutation area still remain the same,and voltage magnitude has decreased so the end of commutation will be delayed and the extinction angle will change from γ to΄ϒ.It crosses its minimum limit.

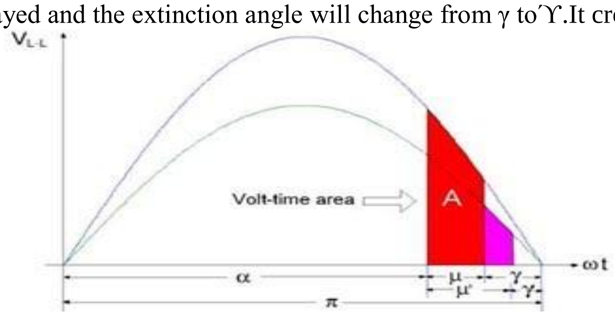


Fig 7 voltage magnitude reduction

2) Increase in dc current

when fault occur at inverter end the dc current increases. Since the volt-time area increases with the increased dc current, a relatively larger overlap μ will be needed to complete the commutation.This reduce the gamma value to its minimum value.

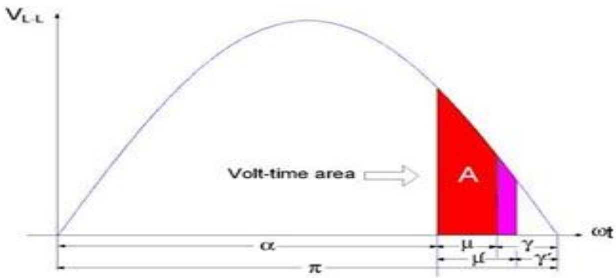


Fig.8 Increase in dc current

THE DIAGNOSIS METHOD FOR COMMUTATION FAILURE:

When the extinction angle gamma reaches to its minimum due to voltage dips in ac systems commutation failures takes place. To be able to keep a gamma in its normal limits, the control system should give an advanced firing instant on detection of the ac system disturbance. It is not possible at all to avoid commutation failure at inverter when sudden increase of dc current and decrease of commutating voltage. However, it could be possible to avoid subsequent commutation failures during the high remaining voltage fault at inverter ac network by advancing the firing angle in order to increase the commutation margin. This makes the system could transfer power during disturbance. There are two possibilities for commutation failure such as commutation voltage reduction or distortion and phase angle jump at unbalanced fault. Therefore, two different sets of control function used to avoid consecutive commutation failure caused by balanced and unbalanced fault.

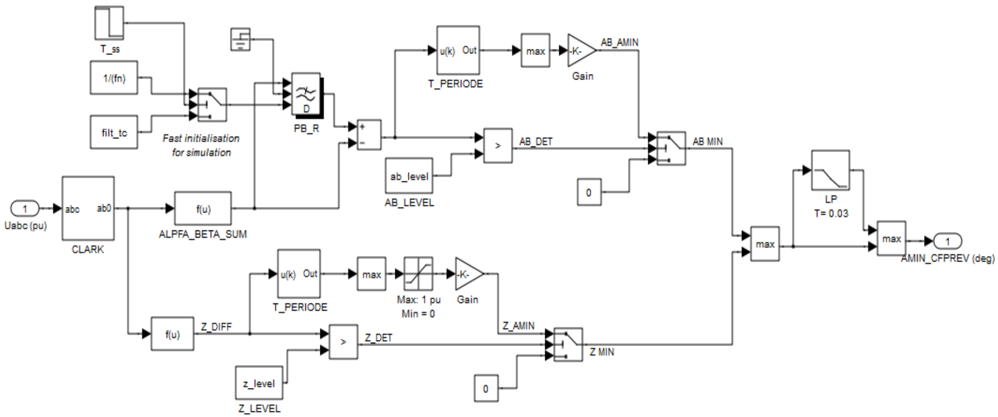


Fig.9 commutation failure prevention block

One parallel path is based on zero-sequence detection to detect single-phase faults, and the other one is based on abc-αβ transformation to detect three-phase faults. This control module is called

CFPREV (Commutation Failure Prevention). Single-phase faults are the most frequently-occurring unbalanced faults experienced by the HVDC converter. The three-phase voltages at the converter bus usually contain zero sequence voltage during this type of fault. Z_DIFF is obtained simply by adding up three-phase instantaneous voltage as

$U_o = U_a + U_b + U_c$ (4)

A MAX_HOLD function with is used to convert the sinusoidal wave shape into a dc quantity. The MAX_HOLD function is so designed that it holds the maximum value it detects and maintains it for certain time , if no bigger value is detected. If Z_DIFF is greater than a predefined level, the signal Z_AMIN from MAX_HOLD will be the angle that will be deducted from the final firing angle .Another part is based on abc-αβ transformation to detect three-phase faults. The idea of abc-αβ transformation is to use one rotating vector to represent three-phase voltages .following equation give the expressions of U_α and U_β used in CFPREV

$U_\alpha = (2/3)U_a - (1/3)\{U_a + U_b\}$ (5)

$U_\beta = (\sqrt{3}/3)\{U_b - U_c\}$ (6)

Since the reduction of voltage at single phase fault is not severe as three phase fault, but creates phase shift. So the unsymmetrical fault is detected by zero sequence voltage detection, then it compared with pre-defined voltage level, if zero sequence voltage is lower than predefined level, it advances the firing angle and keeps it for whole fault duration. Symmetrical fault will not give zero-sequence, therefore it directly compared with predefined value and voltage (prefault voltage – fault voltage) difference, it will decrease the firing angle if the difference is higher than predefined value. In brief, the three phase voltages are transformed to dc quantity by alpha-beta transformation; it gives dc output only when the three phases are symmetrical. However, three phase fault will not decrease the voltage instantaneously in all the phases, it decrease the voltage phase by phase hence creates negative sequence the same happens when clearing the fault. Therefore, oscillations will occur in alpha-beta output. It is not possible to compare the oscillating waveform with pre-fault voltage, so max-hold function is used here to keep the maximum value for half cycle Although the above two parts of the control module deal with different fault conditions, they might be activated at the same time. In such a situation, the maximum value of Z_AMIN and ABZ_AMIN will be chosen as the final output of the entire control module. The output AMIN_CFPREV value will be deducted from the final inverter firing control, advancing the firing instant and leaving a bigger commutation margin.

IV. SIMULATION AND TEST RESULTS

Simulation setup

A simulation model, as shown in Fig 10 , has been developed on Mat lab to study the effect of CFPREV in mitigating commutation failures.

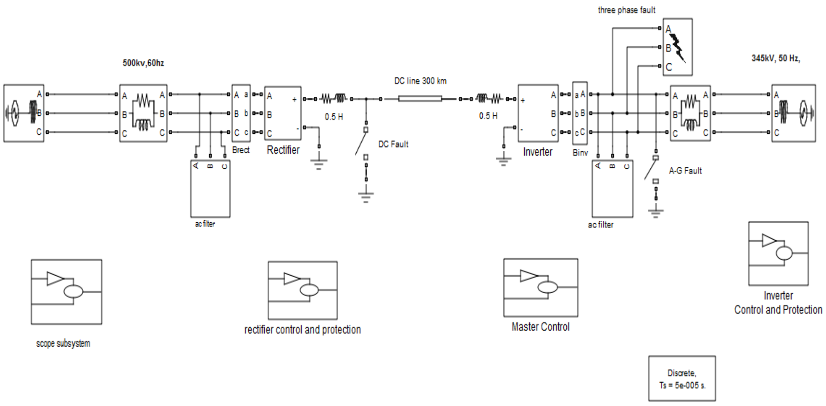


Fig.10 matlab simulation model

Test result:

To test the effect of the commutation failure prevention module (CFPREV), simulation tests were performed to induce commutation failures during single-phase faults and three phase faults.

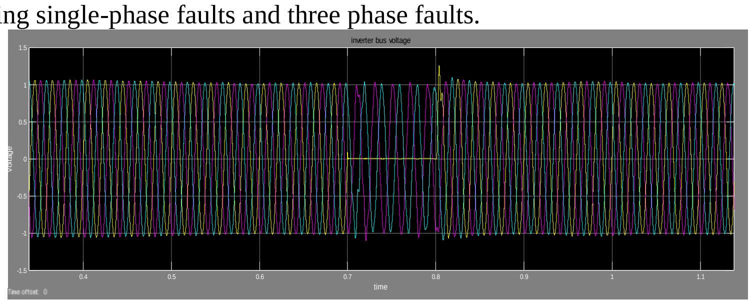


Fig. 11.Inverter bus voltages, during a single-phase fault at the inverter bus.

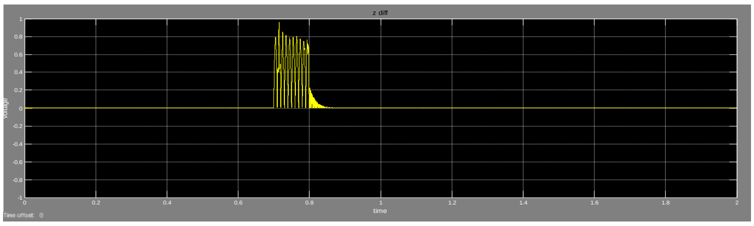


Fig.12 Zdiff, during a single-phase fault at the inverter bus.

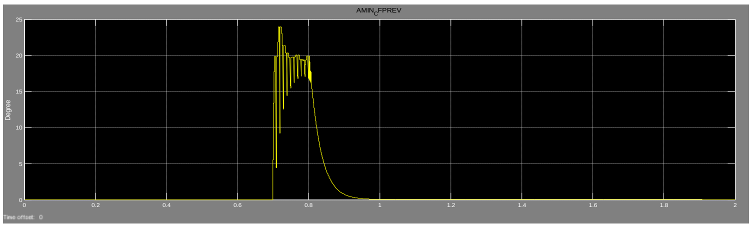


Fig.13 AMIN CFPREV during a single-phase fault at the inverter bus.

Fig. 11,12,13 shows the inverter bus voltages, Z_DIFF, AMIN_CFPREV during a single-phase fault with 20% remaining voltage at the faulted phase. When the fault is applied at 0.7 second, the voltage at the faulted phase drops immediately. The zero-sequence voltage comes up because the three phases are no longer symmetrical. As we have noticed, the zero-sequence voltage is a sinusoidal curve, whose magnitude depends on how high the remaining voltage is at the faulted phase. The MAX_HOLD item maintains the maximum value of Z_DIFF for some time, which converts the sinusoidal curve to a flat curve. The signal AMIN_CFPREV is the final output from CFPREV to the main control system at the inverter station. The contribution AMIN_CFPREV of CFPREV is deducted from the final inverter firing angle.

Waveform during three phase fault :

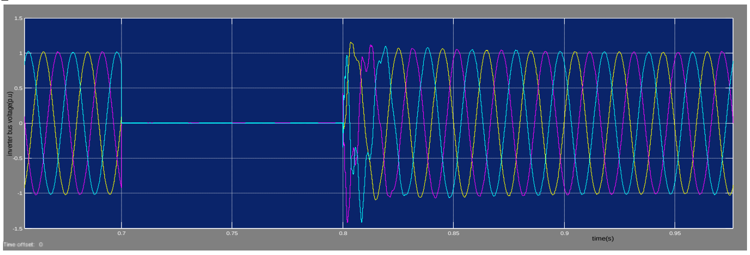


Fig 14.Inverter bus voltages during a three-phase fault at the inverter bus.

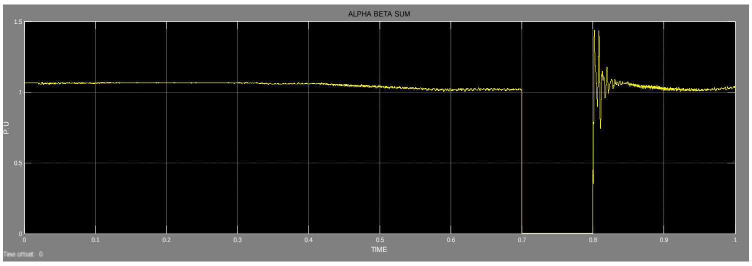


Fig 15. ALPHA BETA SUM during a three-phase fault at the inverter bus.

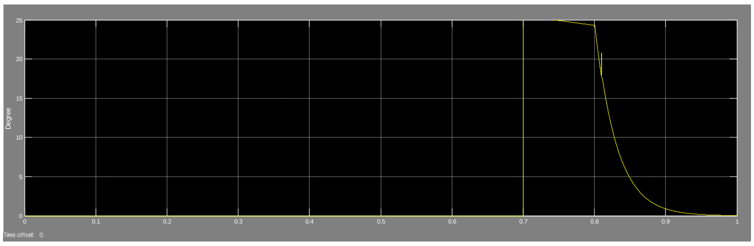


Fig 16 AMIN CFPREV during a three-phase fault at the inverter bus.

V. CONCLUSIONS

This paper presents a novel fault diagnosis method of commutation failure in HVDC system . It has been shown by the simulation model that this method is very effective in reducing the possibility of commutation failures from single phase fault and three phase fault at the inverter..

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