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One of the different kinds of electrical energy is high voltage direct current (HVDC). Some previous researchers work on the Monopolar HVDC systems using Matlab/Simulink environment to carry out their analyses. The analyses that are carried out include single phase to ground fault, double phase to ground fault and three phase to ground fault. It is discovered, among others, that for single phase to ground fault on AC side of the inverter the three phase voltages and three phase currents show no effect except at the rectifier side. But it is clear in our present findings that with reference to single phase to ground fault, the three phase voltages have transient and oscillation waveforms that exclude phase A that decreases to zero and the three phase currents that have a high unstable waveform. We further show that the causes of increase in DC transmission line depend on the severity of the fault that is implemented at the inverter side. There fore, transmission network is extremely important and engineers can use this result when doing their careful analyses.

Keywords: fault analysis, monopolar hvdc, rectifier, inverter, simulation.

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I. INTRODUCTION

Electrical energy is the fundamental, the fact of being necessary for the production, distribution, the use of income wealth, and commodities for the development or progress of a country. It is not possible to make an estimate the great importance

of electrical energy has done in our present day civilization. In fact or in reality, in this present world, the state of relying on electricity is high and it has become a portion of our life. Therefore, we can say that electrical power system is the backbone for the progress of any country in all areas. Similarly, another area of electrical energy is HVDC. This technology is mature and generally approved technology. HVDC is well known as an adequate power system. The HVDC can accomplish as well as being capable of sending sufficient power over several distances. The entire achievements that are used in HVDC rely on the electronic devices such as Gate Turn Off thyristors (GTOs), Insulated Gate Bipolar Transistors (IGBTs), thyristors, semiconductors devices, Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) and mercury arc valves [1] [2] [3]. In addition, HVDC is principally an overhead transmission line over a long distance. In case, there is a fault in the transmission line it will result to total blackout. Therefore, fault analysis will be of great importance to the electric power systems. Some previous researchers work on the HVDC Monopolar systems. For example, [4] Present faults on HVDC Monopolar transmission line such as a performance of the converter, DC faults (voltage & current) and line to ground fault on AC side. They use Matlab/Simulink environment to model and simulate. In their conclusion, it shows that during faulty conditions the voltages waveforms have slight decrease and currents decreases from its standard value [5] work on DC link line to line fault and line to ground fault using Matlab/Simulink environment.

The result shows that when fault occurs on the DC line it decreases and after fault it is hard to go back to its original state. [6] too carried out a proposed model with broad simulation. They carry out their research work by studying suppression of temporary overvoltage during the

various fault conditions such as DC faults, three phase AC fault, single phase AC fault and double phase AC fault and fault recovery using Matlab/Simulink environment. The result shows that optimal PI controller is good on transient performances. Similarly, [7] present transient characteristics of DC line to line fault of HVDC Monopolar system. The model of HVDC Monopolar system was carried out using PSCAD/MATLAB. In their result the DC voltage leads to unstable which is hard to rebalance. [8] too simulate a pole to ground fault on a DC link which results to a low steady state DC fault current and further discovers to have a healthy pole it involves large overvoltage. In addition to their work, they also propose a new strategy of fault protection in HVDC grids. Authors such as [9] focus on pole rebalancing in Monopolar HVDC of DC side. In their paper, they propose post-fault restoration and fault clearing for pole rebalancing in order to deal with DC faults that result to pole-to ground fault. The test is carried out using one of the popular software which is PSCAD/EMTDC. In this paper, we want to continue the discussion of Monopolar HVDC system using Matlab/Simulink environment with accurate detection to differentiate some fault characteristics when fault is applied at the AC side of the inverter.

II. TYPES OF HVDC SYSTEMS

2.1 Monopolar link

It has a single negative polarity connector and closes the current loop with the earth or the sea. In a Monopolar connection, there are two converters at the end of each pole. The grounding

distance between the poles with the substation is fixed at 15-55 kilometers [10].

2.2 Bipolar link

It has two conductors, one of which is negative and the other is positive in relation to the earth or the sea. Each terminal station's converter midpoints are earthed through electrode wires. The voltage between the conductors is double to the voltages between any two conductors and ground [11]. In HVDC system, it is commonly used.

2.3 Homopolar link

This link always operates with the earth or metallic return and has two connectors of the same polarity of the electrodes, which is generally negative. The poles are operated in parallel in a homopolar connection at the moment homopolar system is not in use [12].

III. MATLAB/SIMULINK MODEL OF HVDC MONOPOLAR SYSTEM

The HVDC system is modeled by Matlab/Simulink and Simpower tools in order to determine the fault of the Monopolar HVDC (high voltage direct current) system. A frequency of 60Hz of voltage source feeds a frequency of 50Hz with a load of 50kW through an AC to DC to AC converter. The voltage of 380V is from the secondary transformer of the wye-delta which is first rectified by the six pulse diode universal bridge. The insulated-gate bipolar transistor (IGBT) of the inverter side uses PWM at a 2000Hz carrier frequency (f_c).

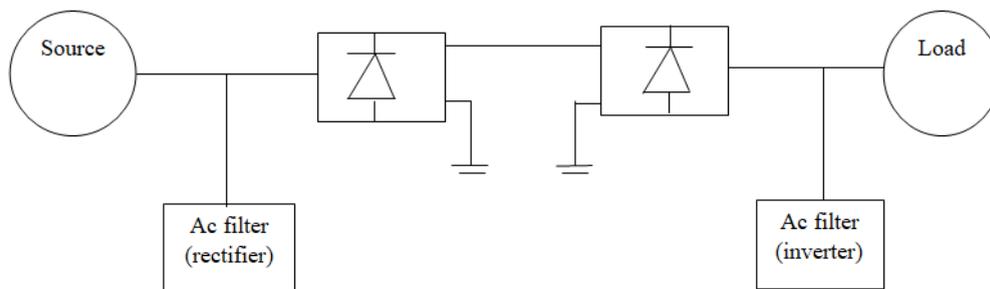


Figure 1: Model of HVDC Monopolar system

IV. RESULTS AND DISCUSSION

4.1 Fault Simulation to Predict Actual Behaviour

The leading importance of this paper is to distinguish different fault conditions when they are applied at the AC side of the inverter and their behaviour on the DC line and at the rectifier side of the source. In this part, it is highly necessary for the engineers to identify where the fault is coming from HVDC power system transmission lines for quick repair so that it can go back to its continuous steady state.

4.2 Three Phase to Ground Fault (Inverter)

The three phase to ground fault (LLLG) is the most grievous fault when compared with the other different faults. At the point when the three phase to ground fault happens, the AC voltages and currents at station 2 (inverter side) which collapse to 0 are shown in figure 2a. The DC voltage will increase with oscillation during fault as shown in figure 2b and at station 1 (rectifier side), the AC voltages will increase from their original values and the currents will decrease from their normal values. Both are shown in figure 2c

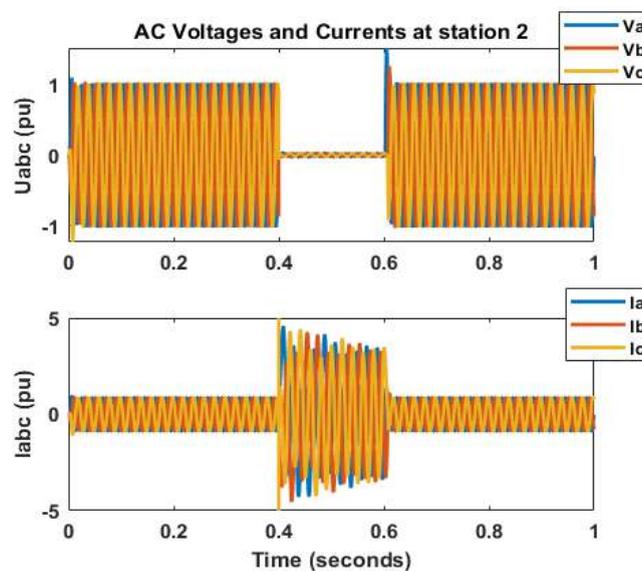


Figure 2a: Simulation Results for Three Phase Voltages and Currents During the Three Phase to Ground Fault (LLLG) at Inverter Side

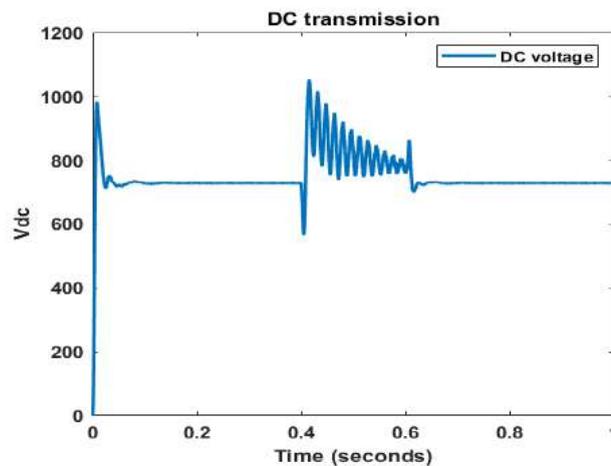


Figure 2b: Simulation Result for DC Voltage During the Three Phase to Ground Fault (LLLG) at Inverte

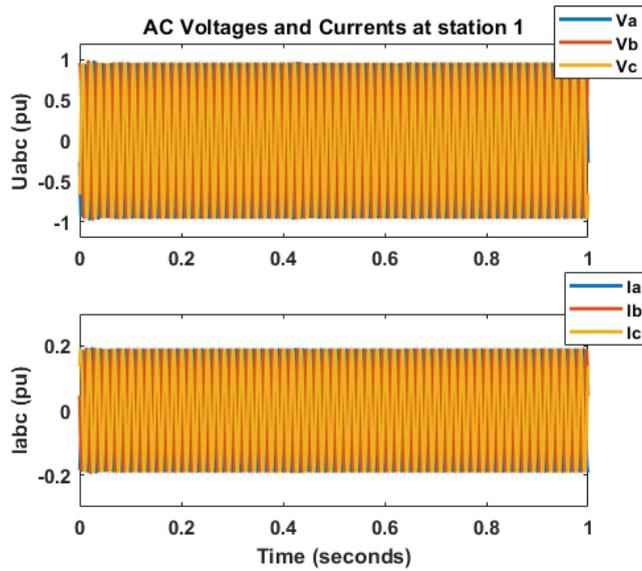


Figure 2c: Simulation results for three phase voltages and currents station 1(rectifier side) during the three phase to ground fault (LLG) at inverter side

4.3 Double Phase to Ground Fault (Inverter)

In the simulation result, the fault was applied at the station 2 (inverter) with duration of 0.2s. The AC voltages (A & B) and currents that become unstable are shown in figure 3a. The DC voltage is affected and increase in waveform during the fault

is shown in figure 3b while the AC voltages and currents are also affected at station 1. The AC voltages slightly increase from the original values while the currents decrease with false waveforms. Both are shown in figure 3c.

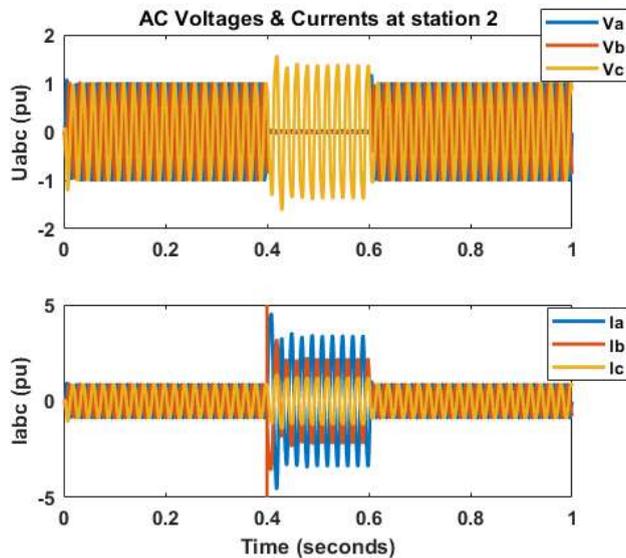


Figure 3a: Simulation Results for Three Phase Voltages and Currents During the Double Phase to Ground Fault (LLG) at Inverter Side

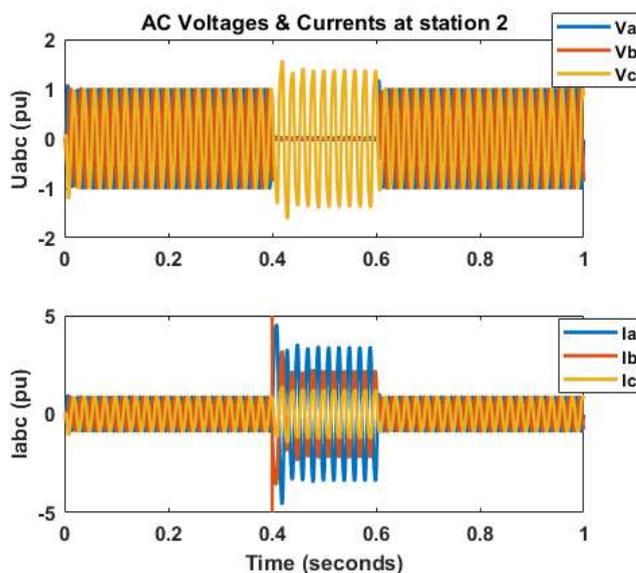


Figure 3b: Simulation Result for DC Voltage During the Double Phase to Ground Fault (LLG) at Inverter Side

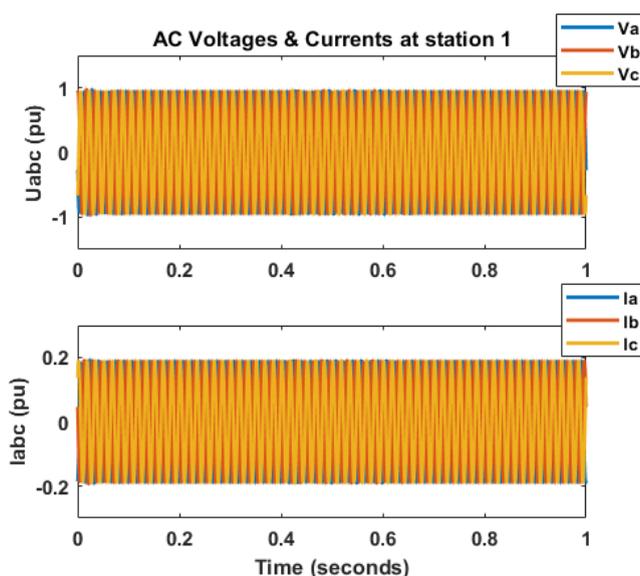


Figure 3c: Simulation Results for Three Phase Voltages and Currents at Station 1(rectifier Side) During the Double Phase to Ground Fault (LLG) at Inverter Side

4.4 Single Phase to Ground Fault (Inverter)

During the fault at 0.2s, the voltage phase A will collapse to 0 and the other phases will maintain unstable sinusoidal waveform and the currents will also show unstable waveform and this state is shown in figure 4a. Meanwhile, the DC transmission is affected having an increase in waveform as shown in figure 4b. The sending end, the AC voltages and currents that have slight increase waveforms are shown in figure 4c.

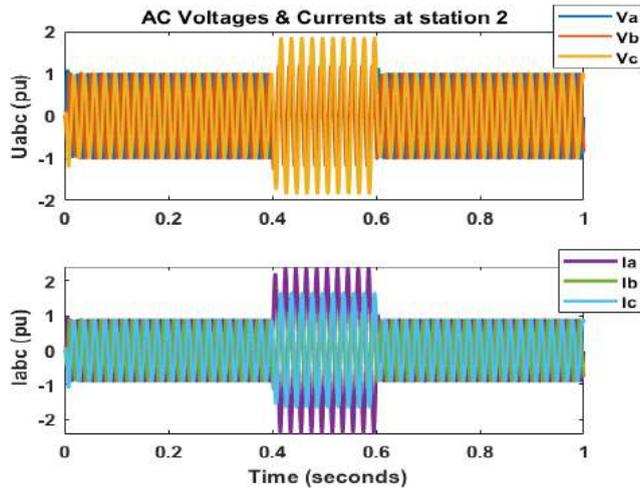


Figure 4a: Simulation Results for Three Phase Voltages and Currents at Inverter Side During the Single Phase to Ground Fault (LG) at Inverter Side

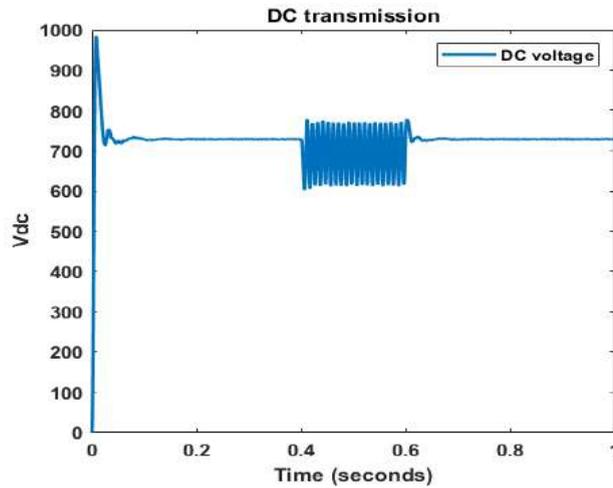


Figure 4b: Simulation Result for DC Voltage During the Single Phase to Ground Fault (LG) at Inverter Side

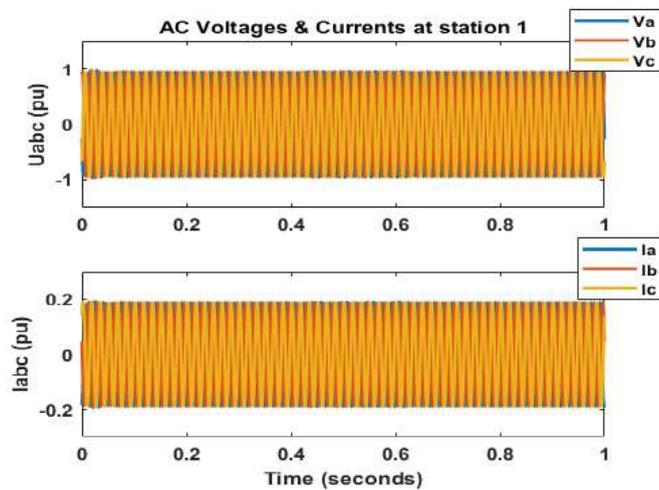


Figure 4c: Simulation Results for Three Phase Voltages and Currents at Rectifier Side During the Single Phase to Ground Fault (LG) at Inverter Side

V. CONCLUSION

In this paper, detection of fault behaviours in High voltage direct current (HVDC) system is carried out due to the alarming rate of power failure. The analyses that are done include single phase to ground fault, double phase to ground fault and three phase to ground fault. The model was carried out using Matlab/Simulink. [4] Shows that when fault was applied on single phase to ground fault at the inverter side on AC side, the voltage would decrease. But it is clear in our present findings that with reference to single phase to ground fault, the three phase voltages have transient and oscillation waveforms that exclude phase A that decreases to zero and the three phase currents that have a high unstable waveform. We further show that the causes of increase in DC transmission line depend on severity of the fault that was implemented at the inverter side. Therefore, transmission network is of extreme importance and engineers can use this result when doing their careful analyses.

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