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CONTROL AND TRANSIENT ANALYSIS OF VOLTAGE SOURCE CONVERTER BASED MULTI TERMINAL DC SYSTEM

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Abstract:
As one of the key technologies of large scale access of distributed energy resources, the HVDC transmission system has great potential for further development. Therefore, in the past decades, the problem associated with HVDC converters connected to weak AC networks has become an important research field. The one of particular interest, and highest in consequences, is the AC voltage stability at the HVDC terminals of the AC/DC systems. Voltage source converter-based HVDC (VSC-HVDC) is a new generation technology of HVDC, which overcomes some of the disadvantages of the traditional thyristor-based HVDC system, with a very broad application prospect. Compared to the conventional HVDC systems, the prominent features of the VSC-HVDC system are its potential to be connected to weak AC systems, independent control of active and reactive power exchange, and so on. Due to those characteristics, many researches have been done for the exploitation of VSC-HVDC to enhance system stability of AC/DC systems, that is, the improvement of transient stability. In this paper, the different transient operation mode are explained. Modeling and Simulation is done using MATLAB.

Key Words:- High Voltage Direct Current (HVDC), Voltage Source Converter (VSC), Multi Terminal Direct Current (MTDC), Transients Analysis Of DC.

I. Introduction

Now it is fully confidential that there is no exaggeration to say that HVDC technology was introduced as a response to the need of having a more efficient and flexible transmission system. This need became more important especially due to increase in electricity demand and number of the renewable energy sources connected to the grid such as wind power sources. HVDC system has been conventionally used to interconnect two AC power systems working either at two different frequencies or at the same frequency but without being synchronized. It is also used as a way of delivering electric power between two distant points through overhead transmission lines or submarine cables. Another feature of HVDC systems which made them to be put into service in parallel with the AC transmission systems is capability of rapidly control on the transferred power. This characteristic can considerably affect the operational flexibility and controllability of the bulk power system. HVDC transmission applications can be broken down into different basic categories. Although the rationale for selection of HVDC is often economic, there may be other reasons for its selection. HVDC may be the only feasible way to interconnect two asynchronous networks, reduce fault currents, utilize long cable circuits, bypass network congestion, share utility rights-of-way without degradation of reliability and to mitigate environmental concerns. In all of these applications, HVDC nicely complements the ac transmission system.

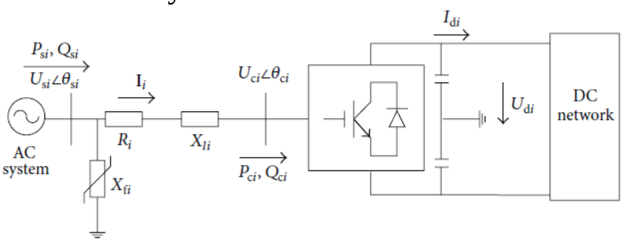

Fig. 1 Simplified circuit diagram of single-phase VSC-HVDC.

11. Why VSC-based Multi Terminal HVDC

Two basic converter technologies are used in modern HVDC transmission systems. These are conventional line commutated, current source converters (CSC) and self commutated, voltage-sourced converters (VSC). Two types of configuration can be adopted in an Multi Terminal DC (MTDC) systems . The parallel connection which allows DC terminals to operate around a common rated voltage V_{DC}. The second configuration is the series connection where one of the converters controls the current around a common rated current and the power is controlled by the rest of converters. This configuration is well suited for Current Source Converter (CSC) MTDC systems since CSCs in the DC side are functioning as a voltage source which can be connected in series without need for special switching.

Compared to CSCs, VSCs are functioning as an ideal current source in its DC sides allowing the parallel connection of several DC terminals without posing any technical difficulties. As perviously mentioned, in a VSC link the direction of power can be changed through the reversal of current direction and the voltage polarity at the DC side can remain unchanged. These capabilities are perfectly suited for constructing an MTDC system. VSC MTDC systems with parallel connected converters have a great potential to be used in the future bulk power systems. Possibility of such connections has led to the proposition of a DC 'Super Grid' that could connect several renewable energy sources to a common MTDC network. Utilizing VSC-based MTDC systems can give the following possibilities to the power systems- (a) Control of the MTDC system,(b) increasing the flexibility of power flow controllability, (c) enhancing transmission capacity, (d) improving the voltage profile in the network, and integrating large scale of renewable or new energy sources positioning at different locations.

III. Control Scheme of the HVDC

The structure of control implemented for the HVDC link of the Fig. is similar to that described in section first depicts the control scheme used for each converter of the DC inter- tie

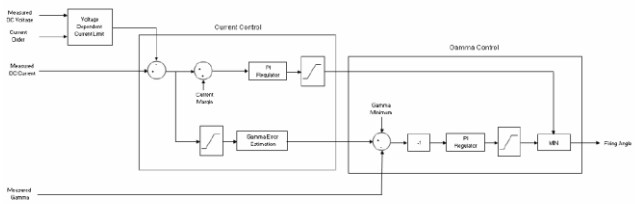

Fig. 2 Block Diagram of Converter Controller

The voltage dependent current order limiter is set according to the characteristic show in Fig.

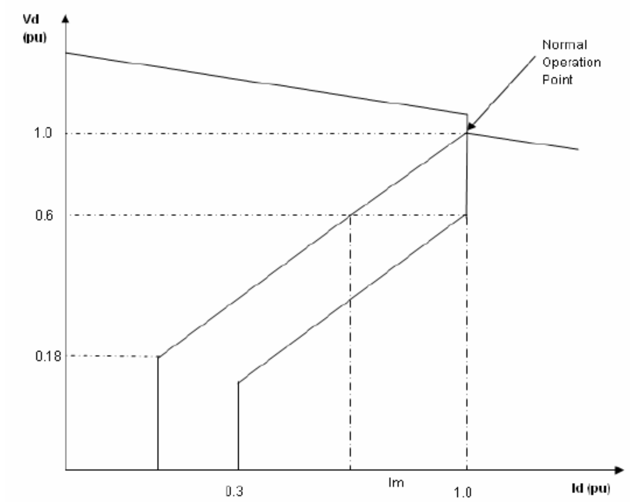

Fig. 3 Voltage Dependent Current Order Limits Used in the Converter Control Scheme

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From an operating point of view it is convenient to control DC power rather than DC current through the HVDC inter- tie. This can be achieved implementing a master power control, which uses a DC power order and the measured DC voltage as inputs. Once the DC voltage is measured, the signal is filtered setting the time constant T1. In the case of low short circuit ratios this time constant must be greater than one second to attain stability in the HVDC link. Furthermore, a minimum DC voltage is set in order to avoid undesirable over currents.

Fast response in the HVDC inter- tie is maintained adjusting the time constant T2 in the lag block ranging from 5 ms to 50 ms. After this some limits in the output current are established and then current orders are sent to each converter control.

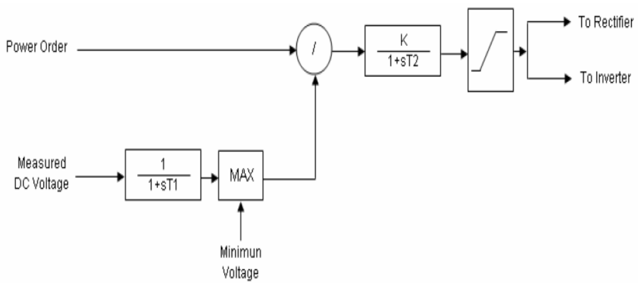
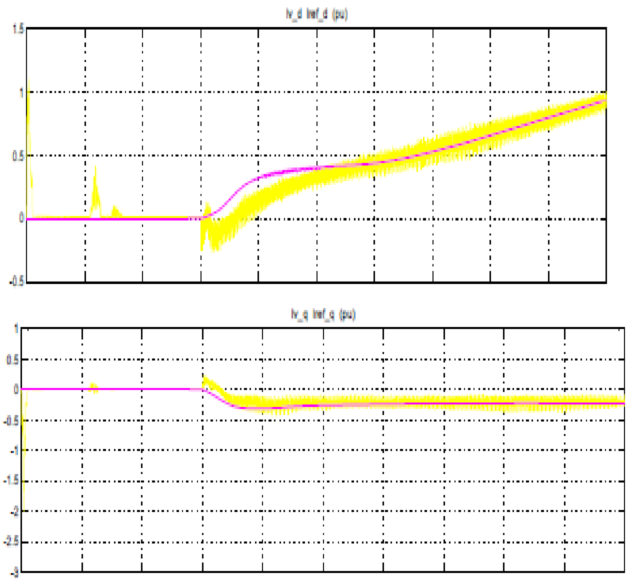
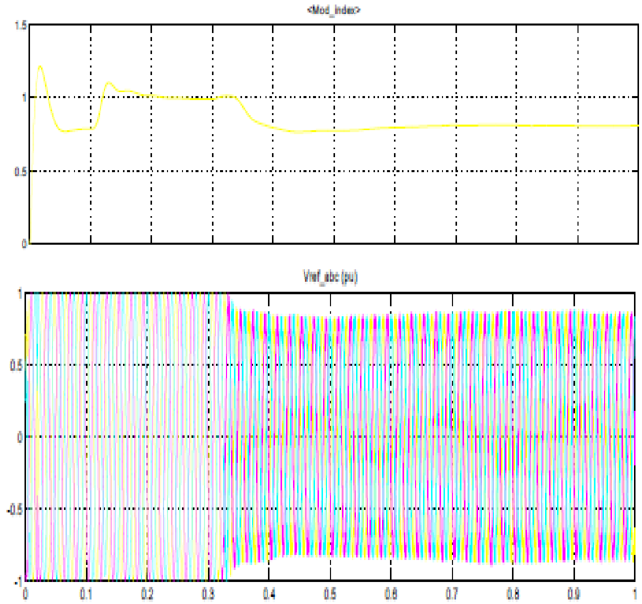
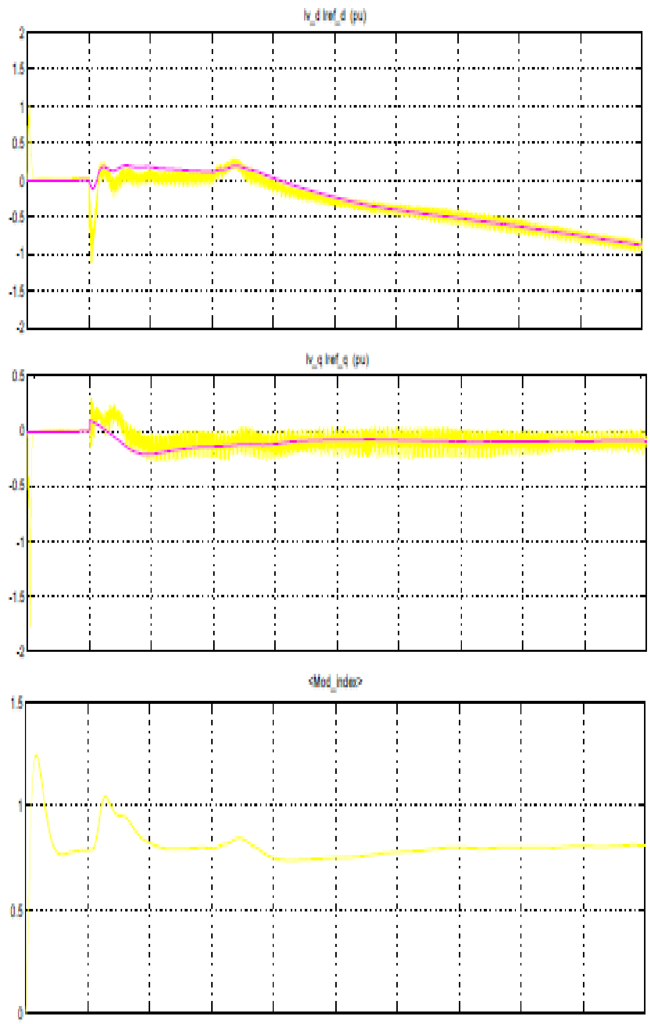


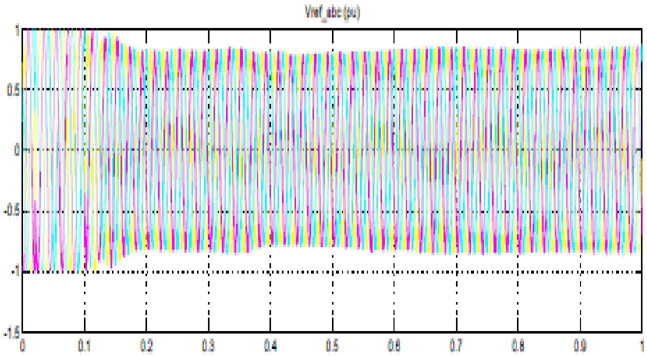
Fig.4 Master Power Control.





Control signal station 1





Control signal 2
Fig.5 Control signal of station 1 and 2

IV. Proposed system

VSC based MTDC system is modeled in MATLAB in this HVDC system 230 kV, 2000 MVA AC systems (AC system1 and AC system2 subsystems) are modeled by damped L-R equivalents with an angle of 80 degrees at fundamental frequency (50 Hz) and at the third harmonic. The VSC converters are three-level bridge blocks using close to ideal switching device model of IGBT/diodes. The relative ease with which the IGBT can be controlled and its suitability for high-frequency switching, has made this device the better choice over GTO and thyristors.

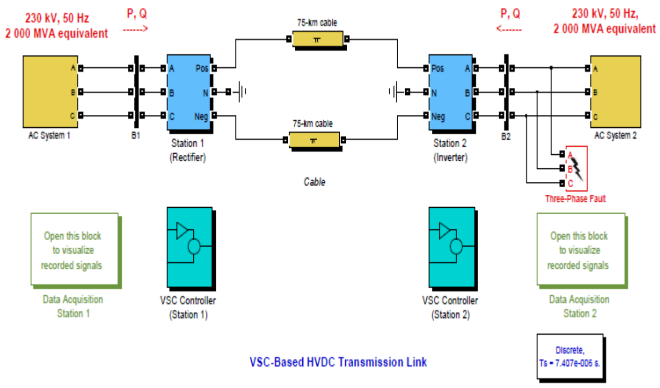


Fig. 6 Proposed VSC -MTDC System

A converter transformer (Wye grounded /Delta) is used to permit the optimal voltage transformation. The present winding arrangement blocks tripplen harmonics produced by the converter. The transformer tap changer or saturation are not simulated. The tap position is rather at a fixed position determined by a multiplication factor applied to the primary nominal voltage of the converter transformers The multiplication factors are chosen to have a modulation index around 0.85 (transformer ratios of 0.915 on the rectifier side and 1.015 on the inverter side).

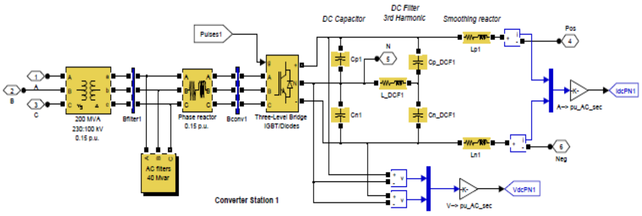


Fig. 7 Converter Station in HVDC

The converter reactor and the transformer leakage reactance permit the VSC output voltage to shift in phase and amplitude with respect to the AC system, and allows control of converter active and reactive power output. To meet AC system harmonic specifications, AC filters form an essential part of the scheme. They can be connected as shunt elements on the AC system side or the converter side of the converter transformer. Since there are only high frequency harmonics, shunt filtering is therefore relatively small compared to the converter rating. It is sufficient with a high pass-filter and no tuned filters are needed. The later arrangement is used in our model and a converter reactor, an air cored device, separates the fundamental frequency (filter bus) from the raw PWM waveform (converter bus).

The reservoir DC capacitors are connected to the VSC terminals. They have an influence on the system dynamics and the voltage ripple on the DC side. The size of the capacitor is defined by the time constant τ corresponding to the time it takes to charge the capacitor to the base voltage (100 kV) if it is charged with the base current (1 kA). This yields $\tau = C \cdot Zbase = 70e\text{-}6 \cdot 100 = 7$ ms with Zbase = 100kV/1 kA.

The DC side filters blocking high-frequency are tuned to the 3rd harmonic, i.e., the main harmonic present in the positive and negative pole voltages.

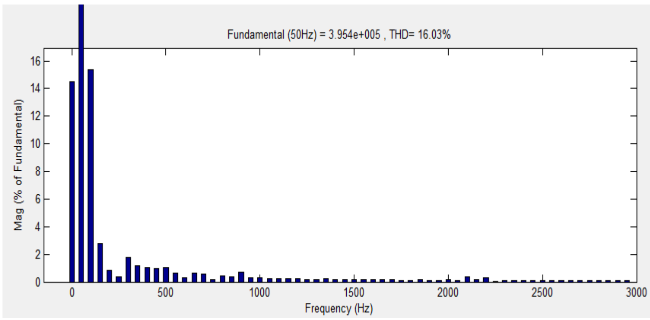
It is shown that a reactive converter current generate a relatively large third harmonic in both the positive and negative pole voltages but not in the total DC voltage. The DC harmonics can also be zero-sequence harmonics (odd multiples of 3) transferred to the DC side (e.g., through the grounded AC filters). A smoothing reactor is connected in series at each pole terminal. To keep the DC side balanced, the level of the difference between the pole voltages has to be controlled and kept to zero (see the DC Voltage Balance Control block in the VSC Controller block). The rectifier and the inverter are interconnected through a 75 km cable (2 pi sections). The use of underground cable is typical for VSC-HVDC links. A circuit breaker is used to apply a three-phase to ground fault on the inverter AC side. A Three-Phase Programmable Voltage Source block is used in station 1 system to apply voltage sags.

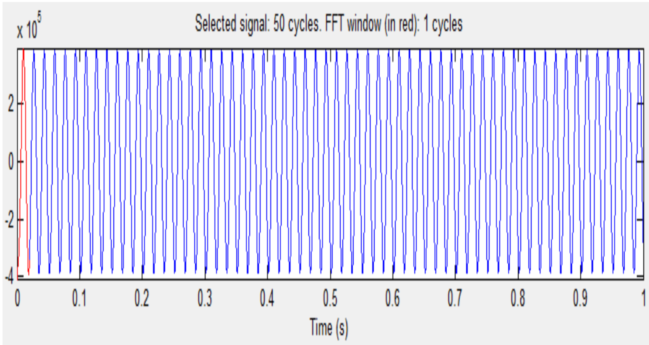
Power can be controlled by changing the phase angle of the converter ac voltage with respect to the filter bus voltage, whereas the reactive power can be controlled by changing the magnitude of the fundamental component of the converter ac voltage with respect to the filter bus voltage. By controlling these two aspects of the converter voltage, operation in all four quadrants is possible. This means that the converter can be operated in the middle of its reactive power range near unity power factor to maintain dynamic reactive power reserve for contingency voltage support similar to a static var compensator. It also means that the real power transfer can be changed rapidly without altering the reactive power exchange with the ac network or waiting for switching of shunt compensation. Fig. shows the characteristic ac voltage waveforms before and after the ac filters along with the controlled items Ud, Id, Q and Uac.

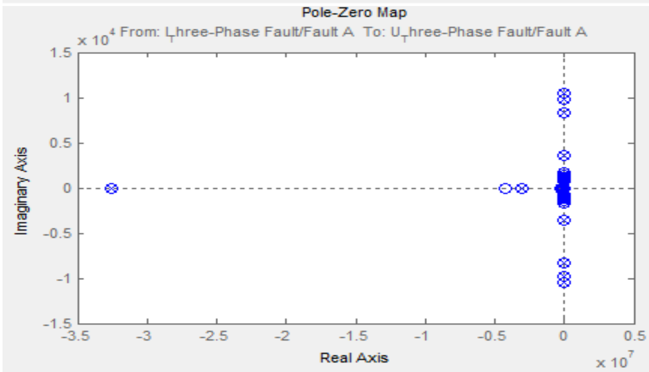
V. Results

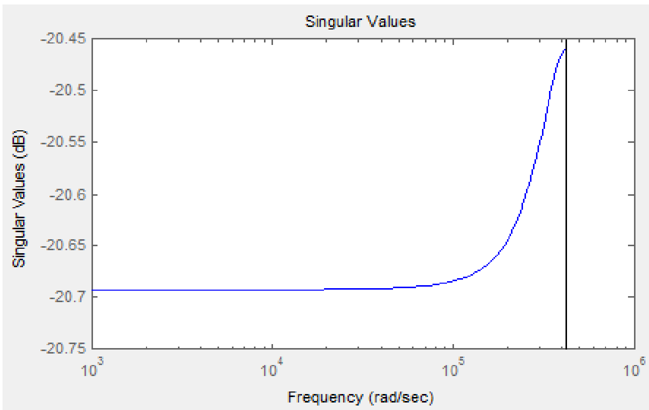
Transient and FFT analysis

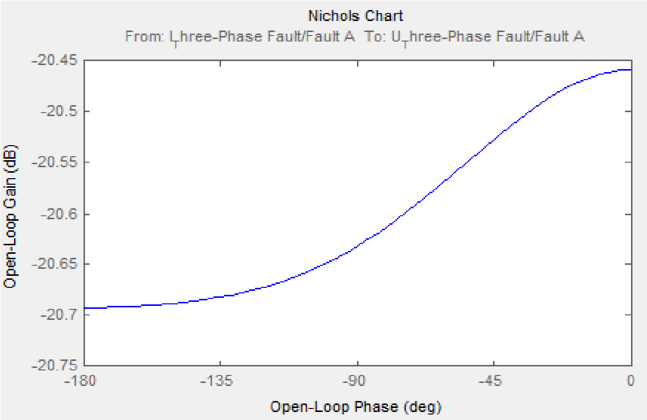
In VSC based MTDC system transient and fft analysis is obtain using simulation in MATLAB, Pole Zero map, singular value, Nichols chart, Nyquist diagram, Bode Diagram, Response in initial condition, impulse Diagram, Step Response also obtain in LTI viewer of MATLAB

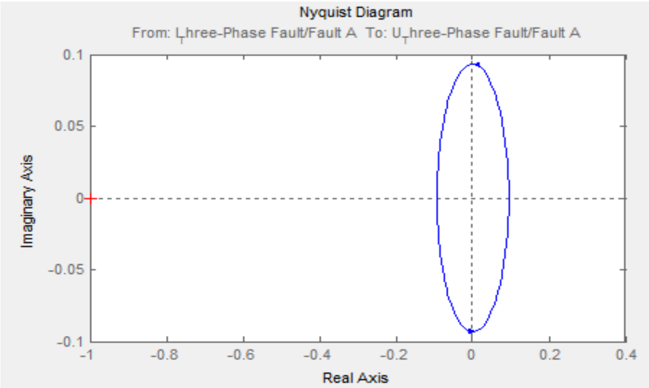


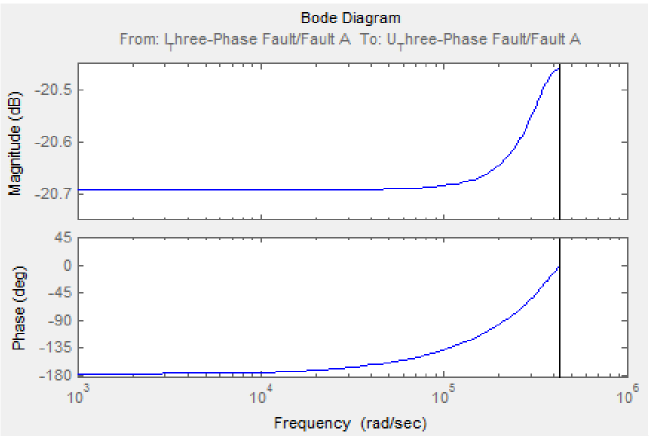


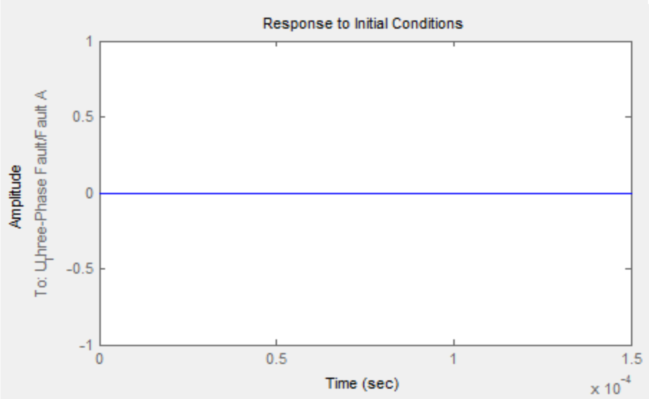


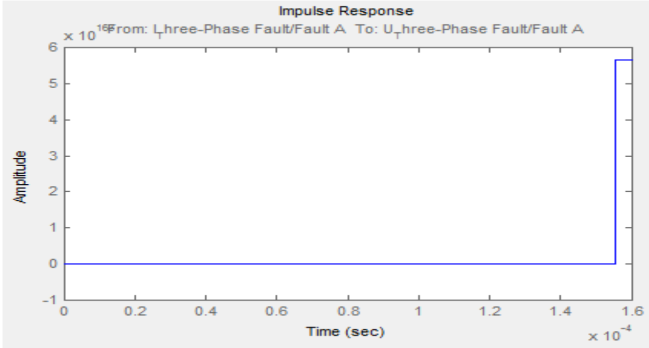












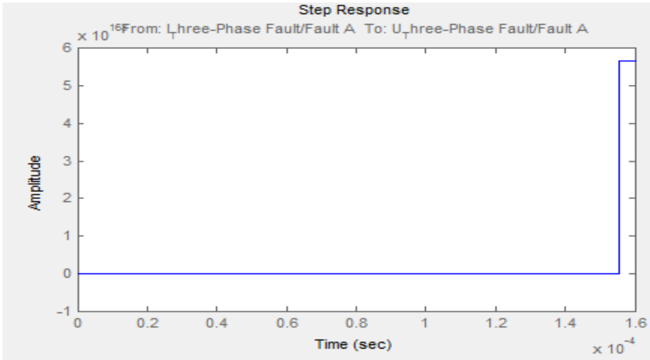


Fig. 8 FFT and Response in different case

VI. Conclusion and Future works

In this paper mainly voltage source converter multi terminal direct current system in high voltage system is proposed, result of both station show the better quality then previous papers performance. In near future due to digital signal technology and fast growing protection and control equipments high voltage dc system beat extra high voltage ac system in each and every performance. In India several HVDC project based on new digital technology running in progress, thanks to power industries which help to develop DC system more accurately to better future of renewable energy and to maintain quality of supply to people.

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