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Exploration of Power System Voltage Stability enhancement through VSC HVDC

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Abstract*-One main problem with respect to AC power transmission is the complexities involved in. This problem may be overcome by using VSC based HVDC system of transmission. In the present work, possibility of using VSC based HVDC transmission for evacuating power is explored.In this paper, an effort has been made to study the typical transmission system consisting of VSC-HVDC connecting two AC grids. Various conditions are simulated using MATLAB software and the steady state and dynamic behavior of the VSC-based HVDC transmission system is analyzed.The power controllability in AC power transmission makes it a complex system.Transient stability issues can be solved by the introducing the High Voltage Direct Current (HVDC) links with the interconnected AC transmission systems.The VSC-HVDC transmission is advantageous in its ability to independently control the reactive and real power flow at each of the AC systems to which it is connected. With the development of VSC technology and pulse width modulation (PWM), the VSC-HVDC can provide a number of potential advantages as compared with classic HVDC. In case of weak AC systems where the conventional line-commutated converter (LCC) based HVDC system has difficulties, the VSC HVDC system proves to be a better solution.

***Index Terms*-HVDC cable, Pulse Width Modulation, Transmission Line, Voltage Source Converter.**

I. INTRODUCTION

Conventional HVDC transmission employs line-commutated, Current-Source Converters with Thyristor valves. These converters require a relatively strong synchronous voltage source in order to commutate. The conversion process demands reactive power from filters, shunt banks, or series capacitors, which are an integral part of the converter station. Any surplus or deficit in reactive power must be accommodated by the ac system. This difference in reactive power needs to be kept within a given band to keep the ac voltage within the desired tolerance. The weaker the system or the further away from generation, the tighter the reactive power exchange must be to stay within the desired voltage tolerance. HVDC transmission using voltage-source converters (VSC) with Pulse-Width Modulation (PWM) was introduced as HVDC Light in the late 1990s by ABB.

These VSC-based systems are force-commutated with Insulated-Gate Bipolar Transistor (IGBT) valves and solid-dielectric, extruded HVDC cables HVDC transmission and reactive power compensation with VSC technology has certain attributes which can be beneficial to overall system performance. VSC converter technology can rapidly control both active and reactive power independently of one another. Reactive power can also be controlled at each terminal independent of the dc transmission voltage level. This control capability gives total flexibility to place converters anywhere in the ac network since there is no restriction on minimum network short-circuits capacity.

Forced commutation with VSC even permits black start, that is, the converter can be used to synthesize a balanced set of 3-phase voltages like a virtual synchronous generator. The dynamic support of the ac voltage at each converter terminal improves the voltage stability and increases the transfer capability of the sending and receiving end ac systems. In the present work, possibility of using VSC based HVDC transmission for evacuating power is explored.

II. LITERATURE REVIEW

An efficient, rapid and independent control over both active and reactive power improves the transient stability. HVDC transmission using voltage-source converters (VSC) with Pulse-Width Modulation (PWM) was introduced as HVDC Light in the late 1990s by ABB Ltd, Sweden. Researcher Kirik studied the effect of VSC HVDC on Long Term Voltage Stability at ABB Corporate research. Dewan et al. studied 'Transient stability enhancement using FACTs controller'. Hafner et al. in a paper of IEEE discusses about 'AC grid with embedded VSC HVDC for secure and efficient power delivery'. Mar Mar Win and The Tin published their work on 'Voltage Source Converter Based HVDC Overhead Transmission System' which is also my base paper.

III. WORK DONE

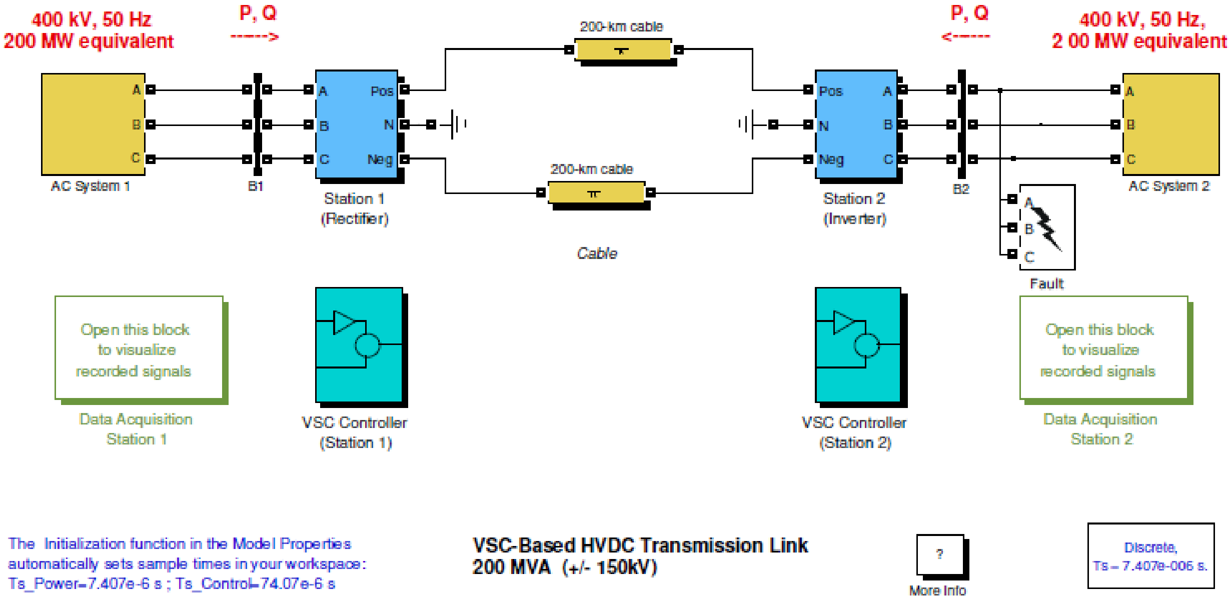

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Fig-1 MATLAB Model for Simulation

A. SYSTEM DESCRIPTION

A 200 MW (± 150 kV) forced-commutated voltage-sourced converter (VSC) interconnection is used to transmit DC power from a 400 kV, 200 MVA, 50 Hz system to another identical AC system [17]. The AC systems (1 and 2) are modelled by damped L-R equivalents with an angle of 80 degrees at fundamental frequency and at the third harmonic. The rectifier and the inverter are three-level Neutral Point Clamped (NPC) VSC converters using close IGBT/Diodes.

The rectifier and the inverter are interconnected through a 100 km cable (i.e. 2 pi sections) and two 8 mH smoothing reactors. The sinusoidal pulse width modulation (SPWM) switching uses a single-phase triangular carrier wave with a frequency of 27 time's fundamental frequency (1350 Hz). 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 0.15 pu phase reactor with the 0.15 pu transformer leakage reactance permits the VSC output voltage to shift in phase and amplitude with respect to the AC system Point of Common Coupling (PCC) and allows control of converter active and reactive power output. 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).

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. The 40MVAR shunt AC filters are 27th and 54th high-pass tuned around the two dominating harmonics.

B. DESIGN PROCEDURE

In the referred work, the rectifier/inverter are three levels VSC that use the IGBT/diode module available in the MATLAB/Simulink/Simpower system. The case study is done for a VSC based HVDC transmission link rated 200 MVA (200MW, 0.95), ±150kv.
The system on AC side has: step down Y-Δ transformer, AC filters, Converter reactor.
The system on DC side has: Capacitors and DC filters.

The design of the components on AC and DC side are shown below.
DC voltage rating: ±150kV
System frequency: 50Hz
Source AC voltage: 400kV line voltage
Rated DC current =Rated DC power/Rated DC voltage
=1.33kA

C. AC SYSTEM MODELING

AC system is modelled as a simple three phase AC source with internal resistance and inductance that is calculated from short circuit level MVA calculations.

(MVA)B = 200MVA
(KV)B = 400 kV (Phase to Phase rms)
$\frac{X}{R} = 10$;
f=50Hz.
Using these details, the Source inductance is found to be 0.2546H
X=0.2546 X 2
$\pi \text{ X } 50 = 80\Omega$

$$R = \frac{X}{10} = 8\Omega$$

D. TRANSFORMER DESIGN

Y grounded /Δ Transformer is used to permit the optimal voltage transformation. It also blocks the triple harmonics produced by the converter.The following data for the transformer is considered:

Nominal Power =200MVA (total for three phases)
Nominal frequency=50Hz.
Winding1 specifications: Y connected,
Nominal voltage = 400kV rms (Line to Line) X 0.915 (to simulate afixed tap ratio) = 366kV
Resistance = 0.0025pu,
Leakage reactance = 0.0075pu
Winding 2 specifications: Δ connected, nominal voltage = 150kV rms (Line to Line), Resistance = 0.0025pu, Leakage reactance = 0.075pu
Magnetizing losses at nominal voltage in % of nominal current: Resistive 5 %(=500pu), Inductive 5 % (500pu).

E. AC FILTERS

Three-phase harmonic filters are shunt elements that are used in power systems for decreasing voltagedistortion and for power factor correction. Nonlinear elements such as power electronic converters generate harmonic currents or harmonic voltages, which are injected into power system. The resulting distorted currents flowing through system impedance produce harmonic voltage distortion. Harmonic filters reduce distortion by diverting harmonic currents in low impedance paths. Harmonic filters are designed to be capacitive at fundamental frequency, so that they are also used for producing reactive power required by converters and for power factor correction. In order to achieve an acceptable distortion, several banks of filters of different types are usually connected in parallel. The most commonly used filter types are Band-pass filters, which are used to filter lowest order harmonics such as 5th, 7th, 11th, 13th, etc. Band-pass filters can be tuned at a single frequency (single-tuned filter) or at two frequencies (double-tuned filter).High-pass filters, which are used to filter high-order harmonics and cover a wide range of frequencies. A special type of high-pass filter, the C-type high-pass filter, is used to provide reactive power and avoid parallel resonances. It also allows filtering low order harmonics (such as 3rd), while keeping zero losses at fundamental frequency. The Three-Phase Harmonic Filter is built of RLC elements. The resistance, inductance, and capacitance values are determined from the filter type and from the following parameters: Reactive power at nominal voltage Tuning frequencies Quality factor. The quality factor is a measure of the sharpness of the tuning frequency. It is determined by the resistance value.The filter is made up of passive R,L,C components their values can be computed using specified nominal reactive power, tuning frequency and quality factor.

Nominal voltage: 150kV
Nominal frequency: 50Hz
Nominal reactive power: 20% of real power (200MW) = 40Mvar
Tuning frequency= 27*50 and 54*50.

Quality factor= 15.

IV. SIMULATIONS RESULTS

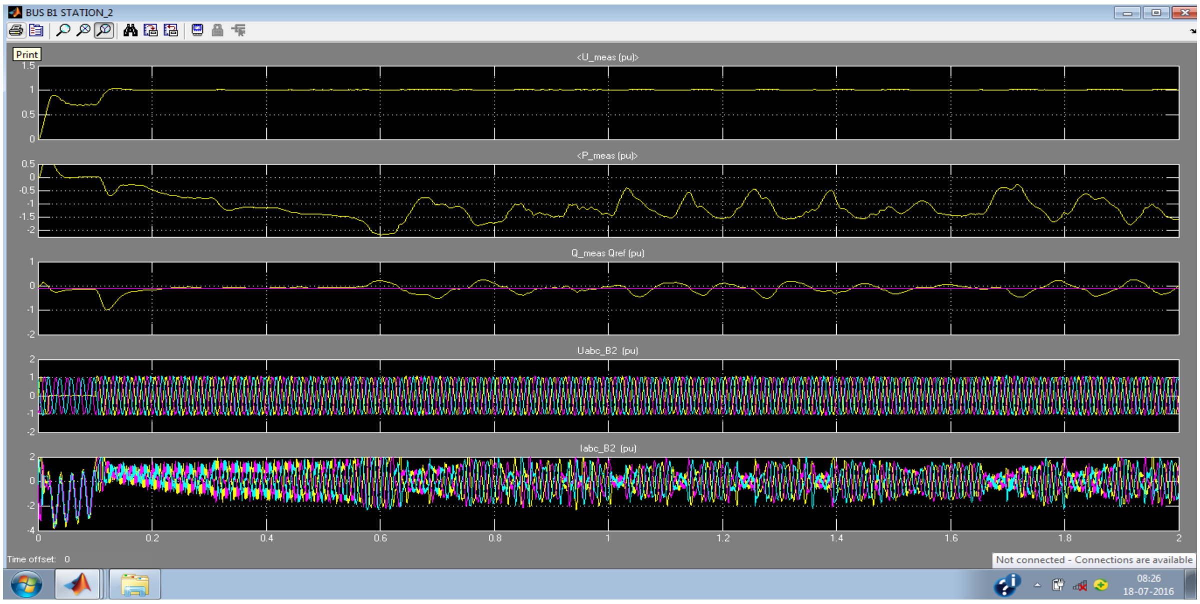

Fig-2Bus Station 2

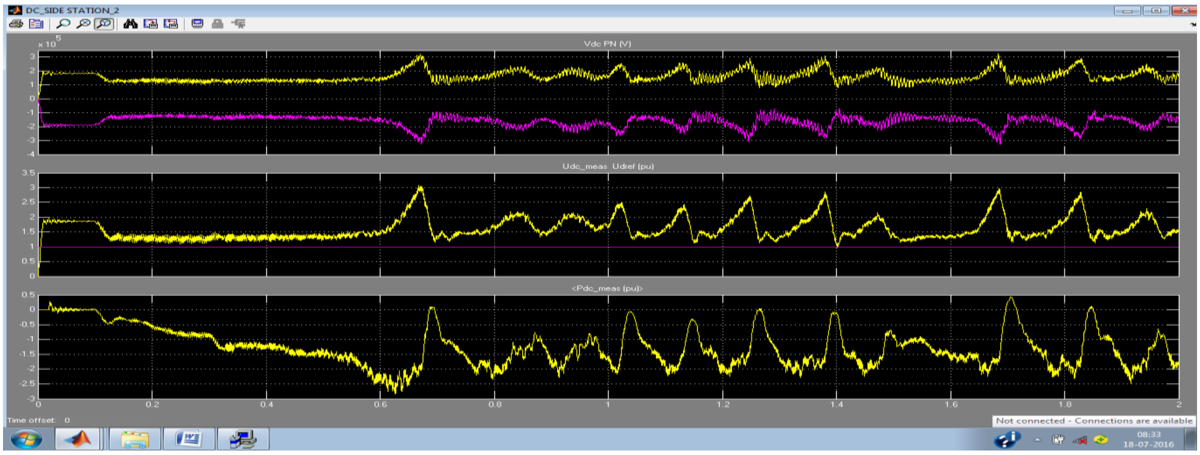

Fig-3 DC side Station 2

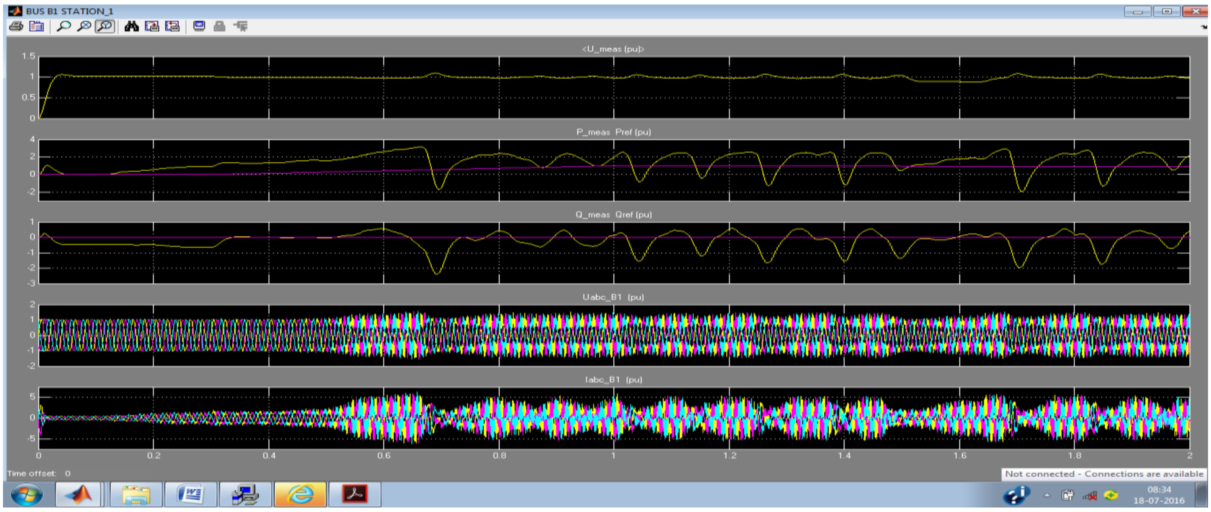

Fig-4. Bus Station 1

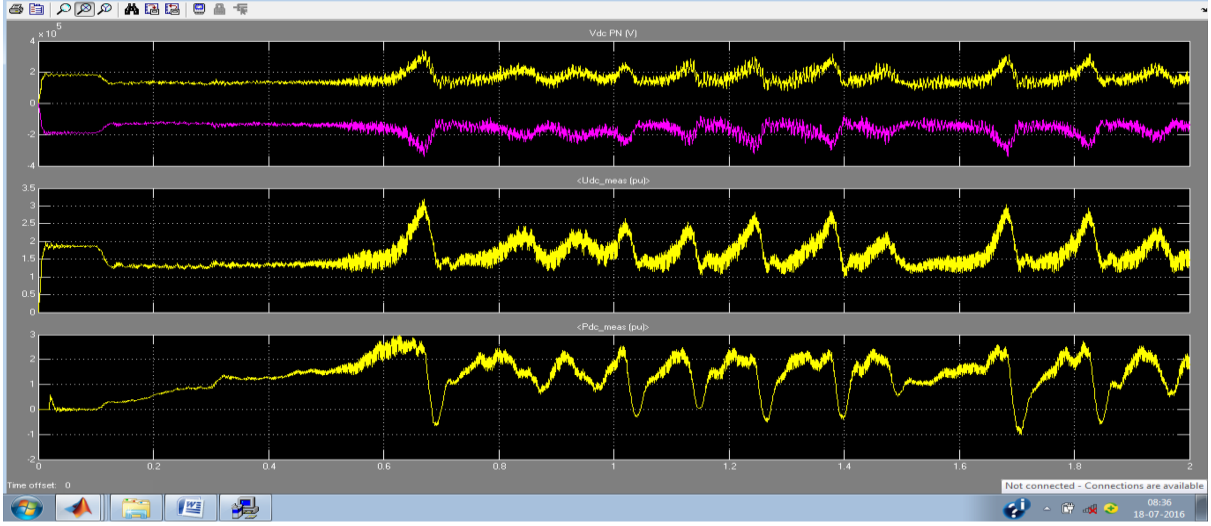

Fig-5. DC Side Station 1

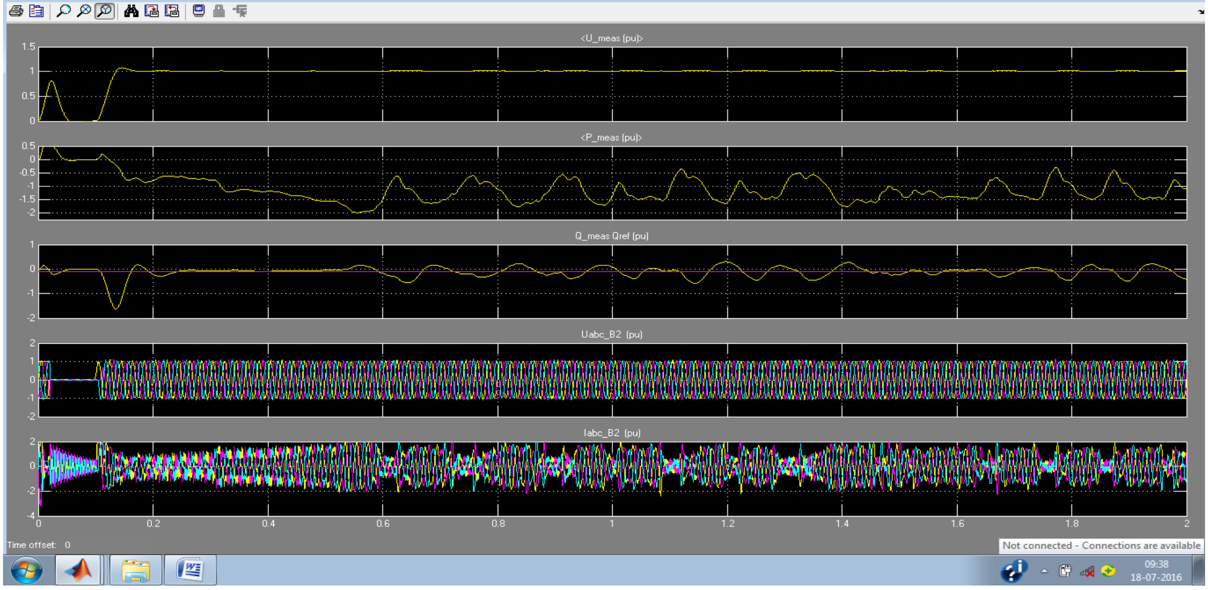

Fig-6.Bus Station 2

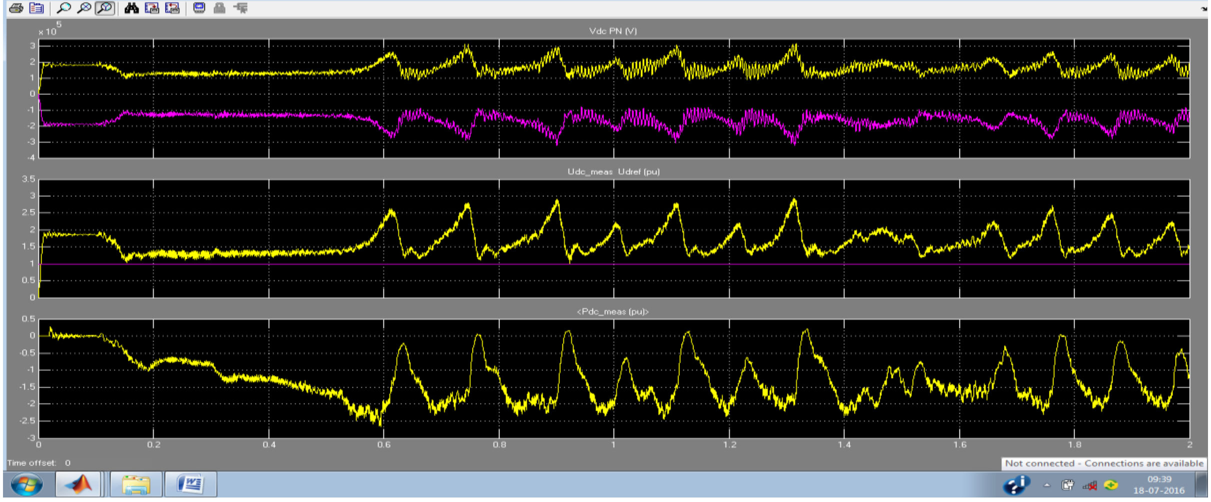

Fig-7. DC side Station 2

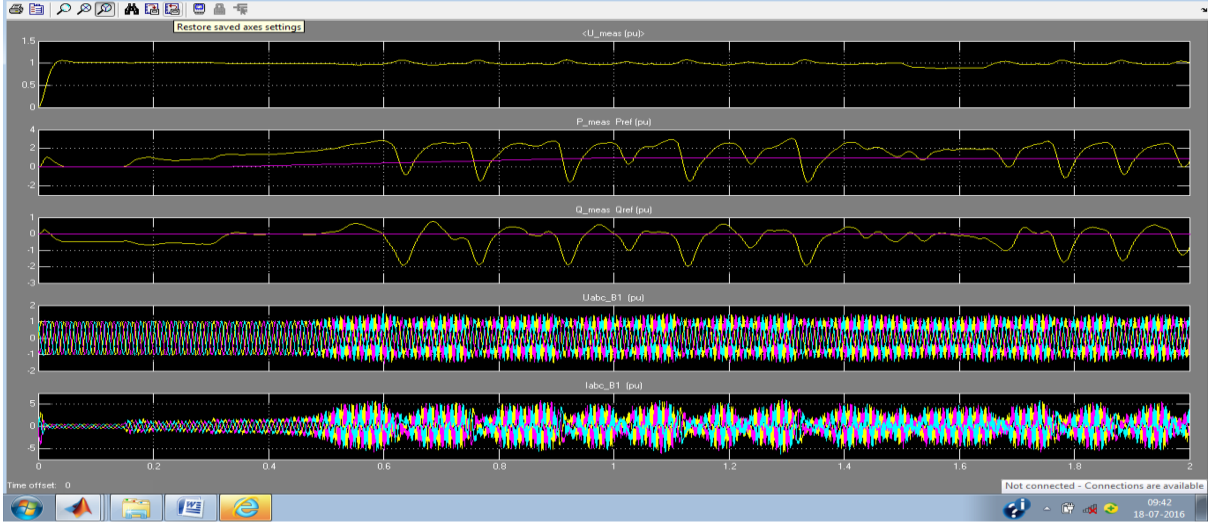

Fig-8. Bus Station 1

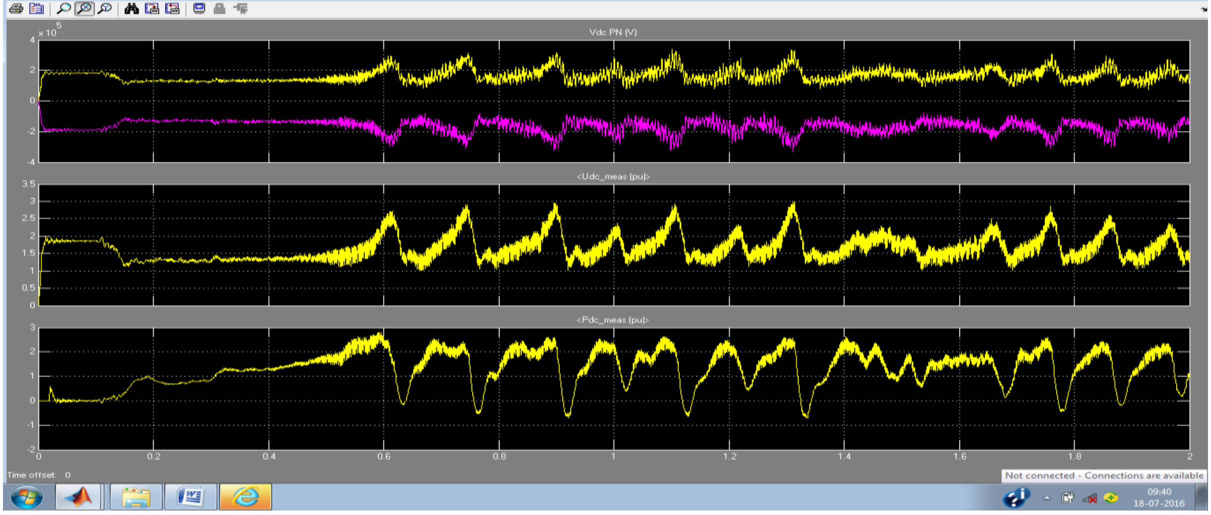

Fig -9. DC Side Station 1

V. CONCLUSION

In this paper an attempt has been made to discuss the steady-state performance of AC Transmission System and VSC based HVDC transmission system. The simulation of HVDC with three levels VSC has been performed. We can deduce from the simulation that with introduction of VSC based HVDC the system response as well as quality of AC signals improves. It also independently controls both Active and Reactive power. The receiving end voltage is maintained at 1 pu despite not providing any voltage compensation.

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