International Journal of Current Research and Modern Education (IJCRME)
ISSN (Online): 2455 – 5428 & Impact Factor: 3.165
Special Issue, NCFTCCPS - 2016

POWER SYSTEM STABILITY ANALYSIS USING FEEDBACK CONTROL SYSTEM INCLUDING HVDC TRANSMISSION LINK

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Abstract:

The dynamics of power systems with high voltage dc (HVDC) transmission links. Small-signal stability, voltage stability, and interaction phenomena of power systems with both line-commutated-converter HVDC (LCC-HVDC) and voltage-source-converter HVDC (VSC-HVDC) are addressed using the proposed platform. In this platform, the entire power system is modeled as a multivariable feedback control system (FCS) which consists of three interconnected blocks. The contents as well as the inputs and outputs of the blocks are selected such that the conventional analysis tools for power system stability are applicable, both in the time and frequency domains. In the FCS model, the relationships between different instabilities are clear, and participant agents of each instability can be determined. The model is developed in a modular and hybrid style, to make it feasible for a large power system. Control of both active and reactive power in voltage source converter (VSC) based High Voltage Direct Current (HVDC) links could be very effective for system stability improvement. The challenge, however, is to properly allocate the overall control duty among the available control variables in order to minimize the total control effort and hence allow use of less expensive converters (actuators). Active and reactive power modulation at the rectifier end, in a certain proportion, turns out to be the most effective. Two scenarios, with normal and heavy loading conditions, are considered to justify the generality of the conclusions. Subspace-based multi-input-multi-output (MIMO) system identification is used to estimate and validate linearized state-space models through pseudo random binary sequence (PRBS) probing.

Key Terms: Voltage Source Converter (VSC), High Voltage Direct Current (HVDC), Multivariable Feedback Control System (MFCS) & pseudo random binary sequence (PRBS)

1. Introduction:

The rapid development of power systems generated by increased demand for electric energy initially in industrialized countries and subsequently in emerging countries led to different technical problems in the systems, e.g., stability limitations and voltage problems. However, breaking Innovations in semiconductor technology then enabled the manufacture of powerful thrusters and, later of new elements such as the gate turn-off thyristor and insulated gate bipolar transistors. Development based on these semiconductor devices first established high-voltage dc transmission technology as an alternative to long-distance ac transmission. HVDC technology, in turn, has provided the basis for the development of flexible ac Transmission system equipment which can solve problems in ac transmission. As a result of deregulation, however, Operational problems arise which create additional requirements for load flow control and needs for ancillary services in the system. This paper summarizes Flexible ac transmission system, High- Voltage DC Transmission, FACTS devices, Power transfer controllability, Faults in HVDC System. During the state of power exchange in interconnected lines to a substation under variable or constant power, the HVDC converters comprehends the power conversion and later stabilizes the voltage through the lines giving a breakeven margin in the power transmission. The first large-scale thyristors for HVDC were developed decades ago. HVDC became a conventional technology in the area of back-to-back and two- terminal long-distance and submarine cable schemes. However, only few multi terminal schemes have been realized up to now. However, further multi terminal HVDC schemes are planned in the future. The main application area for HVDC is the interconnection between systems which cannot be interconnected by AC because of different operating frequencies or different frequency controls. This type of interconnection is mainly represented by back-to-back stations or long-distance transmissions when a large amount of power, produced by a hydropower plant, for instance, has to be transmitted by overhead line or by submarine cable.

2. Types of HVDC Connections:

HVDC became a conventional technology in the area of

- Back-to-back
- Multi- terminal HVDC
- long-distance HVDC

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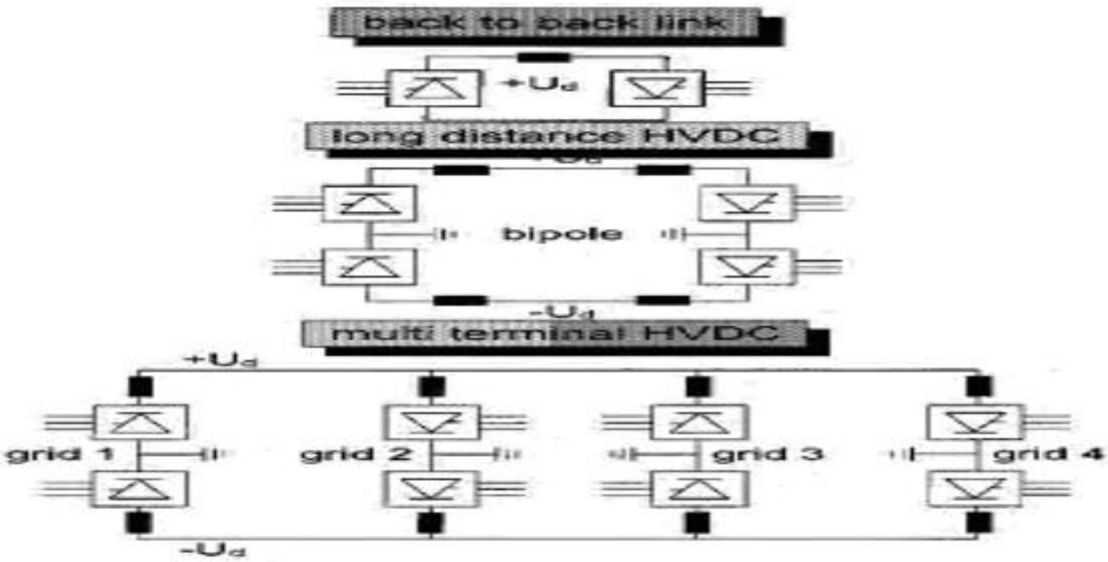

Figure 1: Various types of HVDC Connections

3. The Proposed Scheme:

The 230 kV, 2000 MVA AC systems (AC system1 and AC system2 subsystems) are modeled by damped LR 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. Open the Station 1 and Station 2 subsystems to see how they are built. 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). 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 allow 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 AC harmonics generation mainly depends on the

- Type of modulation (e.g. single-phase or three phase carrier based, space vector, etc.)
- Frequency index p = carrier frequency / modulator frequency (e.g. p = 1350/50 = 27)
- Modulation index m = fundamental output voltage of the converter / pole to pole DC voltage

The principal harmonic voltages are generated at and around multiples of p. The shunt AC filters are 27th and 54th high pass totaling 40 Mvar. Fig 2. To illustrate the AC filter action, we did an FFT analysis in steady state of the converter phase A voltage and the filter bus phase A voltage, using the Powerful block.

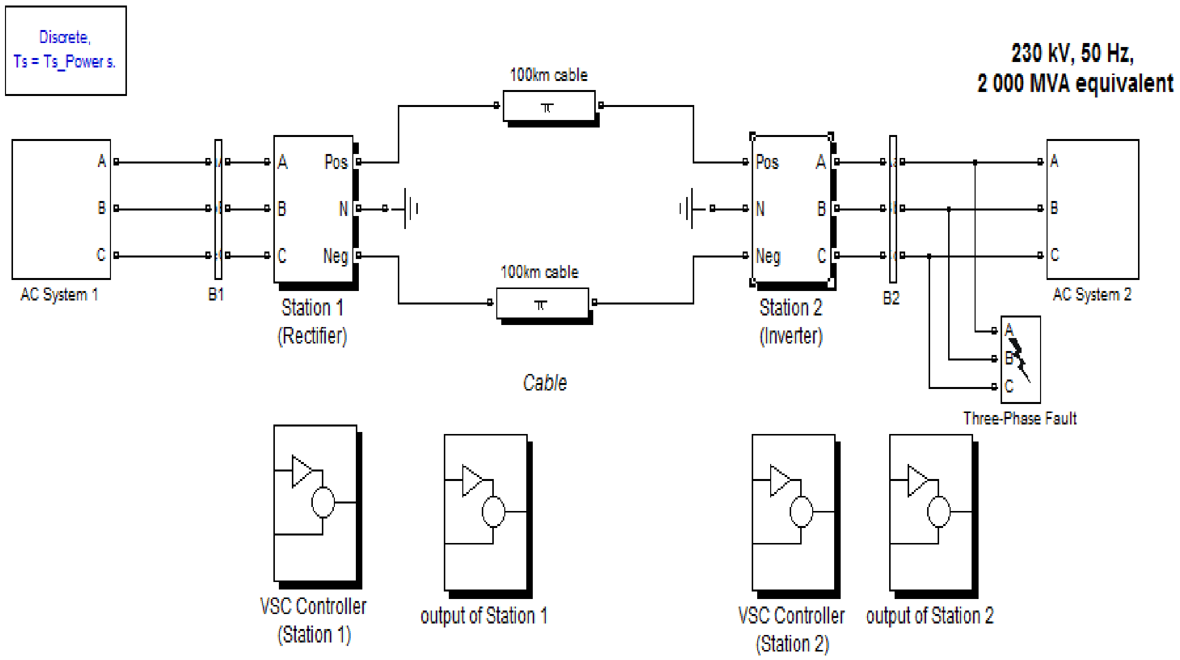

Figure 2: VSC-HVDC Transmission System Model

4. Results and Discussion:

The dynamic performance of the transmission system is verified by simulating and observing the

- Dynamic response to step changes applied to the principal regulator references, like active/reactive power and DC voltage
- Recovery from minor and severe perturbations in the AC system

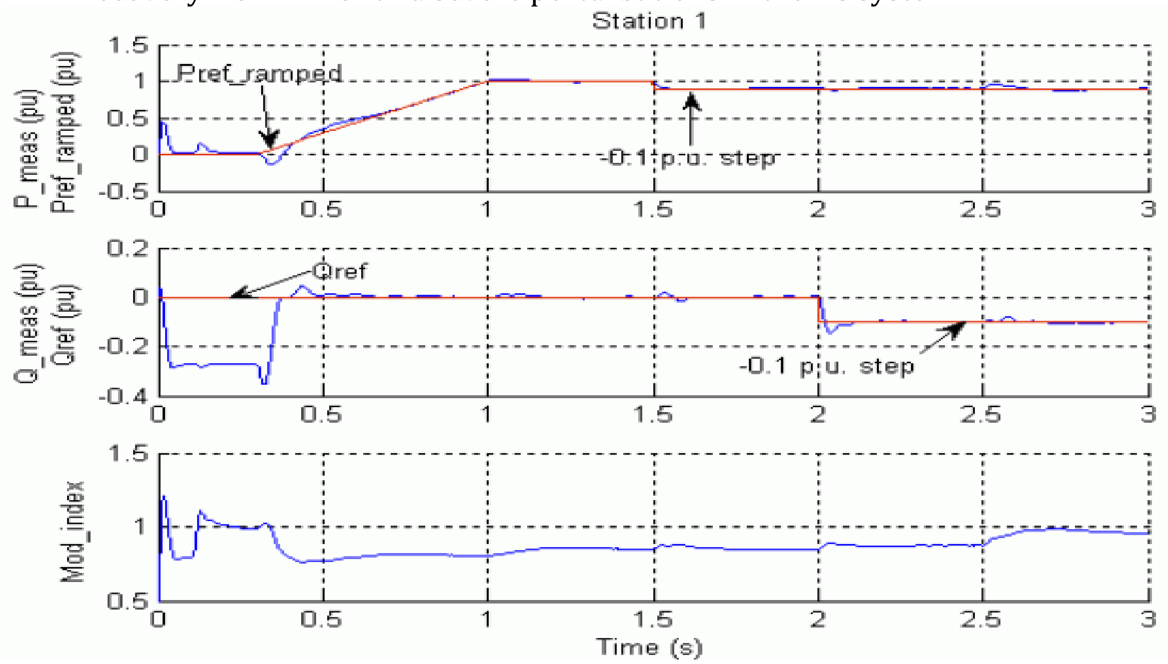

Figure 3: Startup and P & Q Step Responses in Station 1

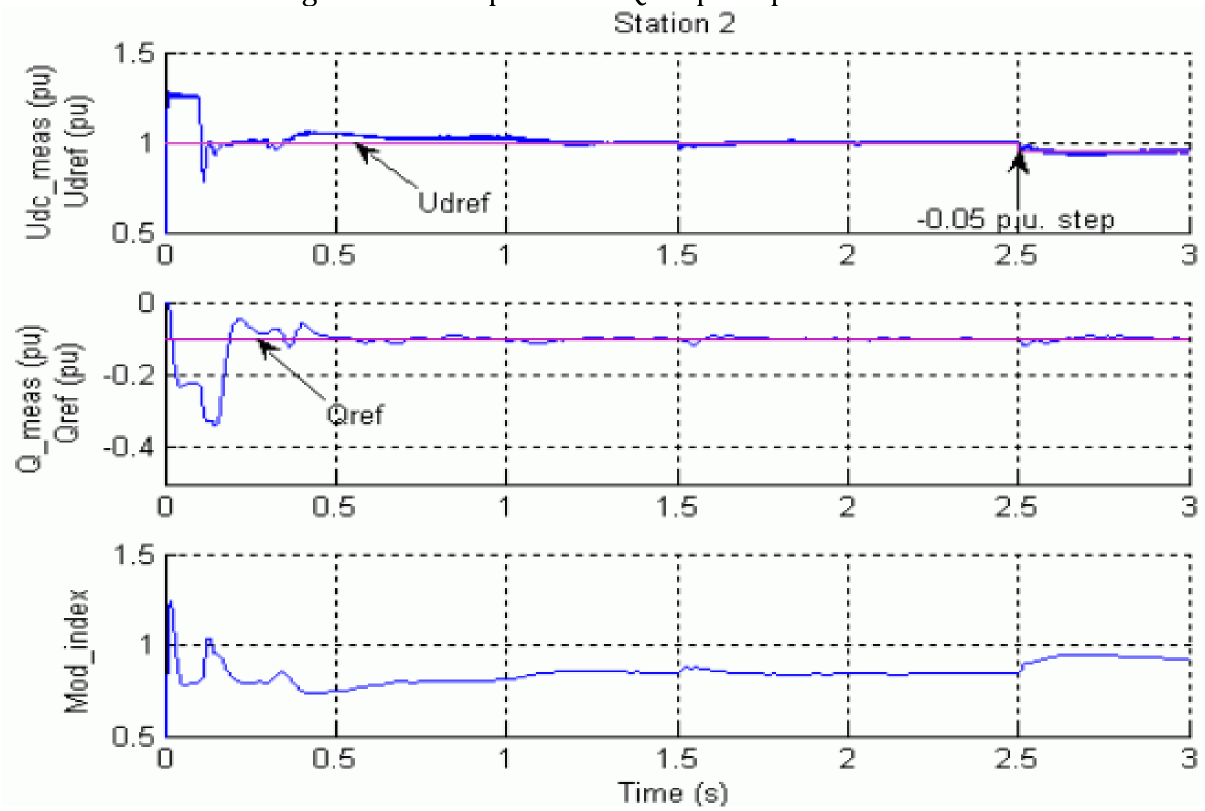

Figure 4: Startup and Udc Step Response in Station 2

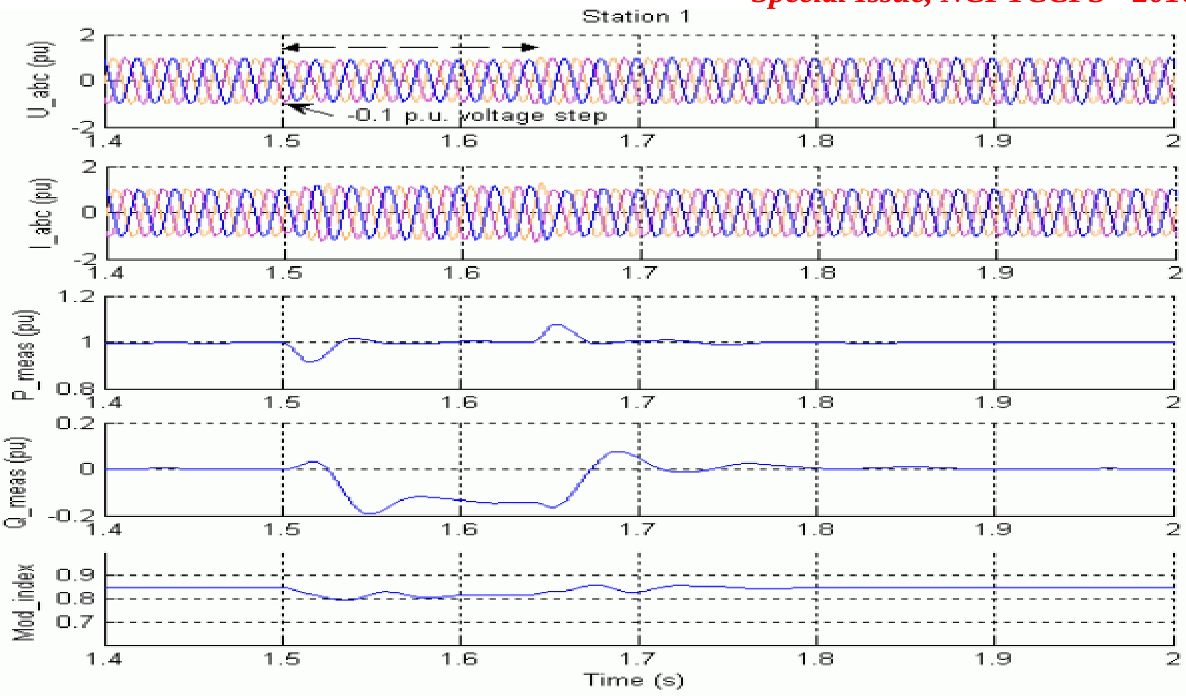

Figure 5: Voltage Step on AC System 1

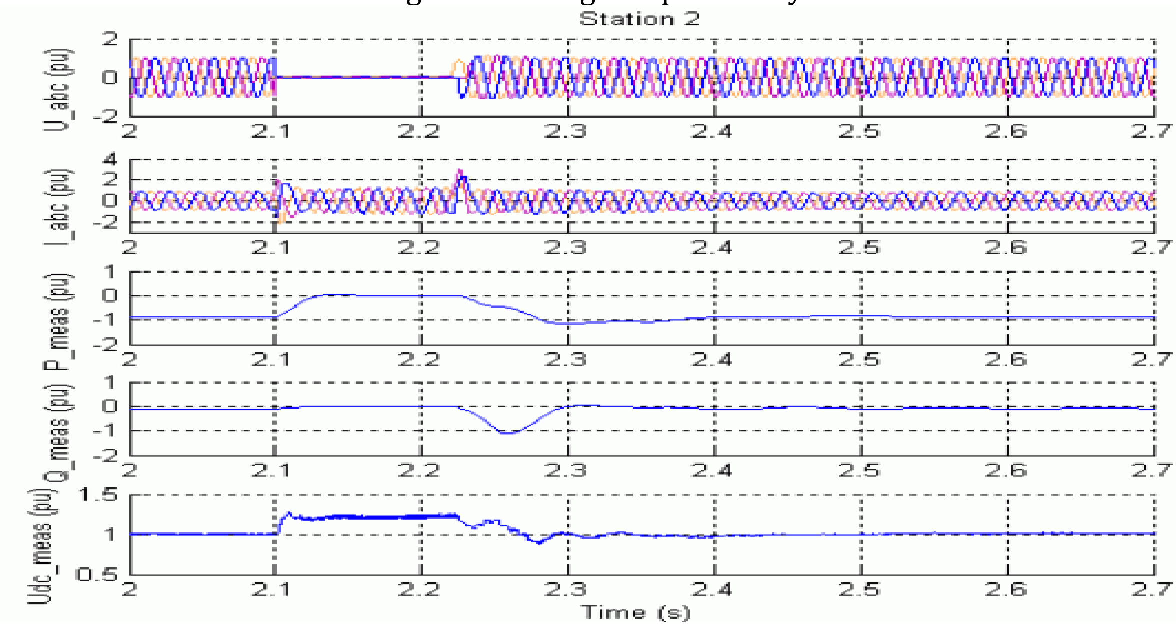

Figure 6: Three Phase to Ground Fault at Station 2 Bus

5. Conclusion:

The proposed project is to improve the dynamic performance of VSC of the interconnected power system by considering DC tie line. A simple but practical controller is presented to improve the dynamic response of VSC system in a realistic power system environment considering DC tie lines in parallel with AC tie lines. The output feedback controller for the power system with DC link gives better dynamic response having relatively smaller peak overshoot and lesser settling time with zero steady state error as compared to the power system considering AC tie lines.Dynamic responses are obtained for wide range of variation in load disturbance from 1% to 4% which satisfy the LFC requirements. Hence for all practical purposes, the controller is quite robust. The simulation results show that proposed control strategy considering parallel AC-DC tie line is very effective and guarantees good performance.

6. Acknowledgement:

The authors would like to thank the management of Muthayammal Engineering College for providing us the support to publish this completion of research work.

7. References:

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