DYNAMIC STABILITY IMPROVEMENT OF POWER SYSTEM WITH VSC-HVDC TRANSMISSION

R.Vasudevan #1, Mrs.S.Ramalakshmi M.E, #2

#1PG scholar & Prist University, #2 Assistant professor& Prist University

Department of electrical and electronics engineering & Prist University, Thanjavur, Tamilnadu, India

[1] vaasu2666@yahoo.com

ABSTRACT

A new control approach for the reactive-power injections of Voltage Source Converters in High Voltage Direct Current (VSC-HVDC) multi-terminal Systems to improve power system transient stability. A reactive-power supplementary signal is provided for each converter. Its value is proportional to the frequency deviation of its corresponding AC bus with reverence to the weighed-average frequency of the multiterminal system stations. The purpose is to increase (decrease) the electromagnetic torque of generators close to those terminals in which the frequency is above (below) the weighed-average frequency used. The AC frequency for all VSC stations is forever available locally for synchronization purposes and could be used by a central controller. Simulations have been carried out using PSS/E and the results have shown that transient stability can be enhanced using this strategy. Since this approach uses global capacity of all VSC stations, the collision of the communication delays has been analyzed, closing that the negative effect is small, for realistic latency values.

KEYWORDS: VSC HVDC, HVDC transmission, multiterminal, transient stability, reactive power, power systems

INTRODUCTION

Development of High Voltage Direct Current (HVDC) technology has brought to considering a meshed Multi-terminal Direct Current (MTDC) network into future power system planning. As the power systems are becoming more consistent and power production more decentralized, MTDC seems as a solution for power transfer over large distances and increasing security of supply. On the other hand, the require to scale up power systems, and higher in feed of power coming from renewable energy sources, resulted in a higher demand for control reserve. Control reserve is defined as methods for keeping the balance between shaped and consumed electrical energy, even in the case of severe disturbances. The goal of this master's thesis was to find a solution for negligible power reserve activation, in systems that contain MTDC networks. This thesis provides an answer to synchronized reserve operation between different areas, by using a control arrangement that is developed for MTDC networks. An original perception of control reserve operation is presented, that increases the security of supply while dropping operational costs of activating control reserve.

The development of high voltage direct current (HVDC) links provides an alternative solution for the competent and flexible transmission of electrical energy that can support the future power system along multiple dimensions. First, during standard operation, HVDC links provide an augmented controllability of the AC power system's in commission point. Power system operators can use HVDC links to optimize the AC power flow in the network in order to avoid congestions and to achieve an economic gain. Secondly, during dynamic situations, HVDC links can be used by a fast automatic grid controller to support the power system's transient stability. This theory studies the control of HVDC injections in power systems during active scenarios. Coordinated HVDC control has a large potential for the dynamic performance of power systems, for instance by growing the damp of power oscillations, but is at present not subjugated in a systematic way.

The aim is to enlarge a framework for power system control through HVDC transmission links. Starting with results for classical AC networks, the thesis presents power system models, operation approaches and network planning methods in the context of dynamically controlled HVDC links. The modeling of power systems with HVDC links has to incorporate quite a few physical and operational constraints imposed by the HVDC links and the surrounding AC network. An account of the resulting constraints on the HVDC injections is particular significant if the HVDC links are to be used for dynamic power system control. Classical capability charts of HVDC links assume a strong AC network connected to a single HVDC link with retreating impedances in the AC transmission system. This results in simple active and reactive power bounds on the HVDC injections. In this thesis, it is shown that this concept can be widespread to restraint sets that are characterized without these simplifying assumptions.

RELATED WORKS

In [1] Jef Beerten, Stijn Cole, and Ronnie Belmans et al presents the addition of electromechanical stability models of voltage source converter high voltage direct current (VSC HVDC) to multi-terminal (MTDC) systems. The paper introduce a categorize reproduction with a cascaded DC voltage control at every converter that allows a two-terminal VSC HVDC scheme to cope with converter outages. When extensive to an MTDC system, the model obviously evolves into a master-slave set-up with converters captivating over the DC voltage control in case the DC voltage controlling converter fails. It is shown that the replica can be used to comprise a voltage droop control to share the power imbalance after a contingency in the DC system surrounded by the converters in the system. Finally, the document discusses two probable model reductions, in line with the assumptions made in transient stability modeling. The straight algorithms and VSC HVDC systems have been implementing by MatDyn, an open source MATLAB passing steadiness program, as well as the commercial power system imitation package EUROSTAG. Two important extensions are added to the model

In [2] Stijn Cole, Jef Beerten, and Ronnie Belmans et al present a new general voltage source converter high voltage direct current (VSC MTDC) model is resulting mathematically. The full system model consists of the converter and its controllers, DC circuit equations, and coupling equations. The main donation of the new model is it's valid for every possible topology of the DC circuit. Practical implementation of the model in power system stability software is discussed in detail. The generalized DC equations can all be articulated in terms of matrices that are byproducts of the construction of the DC bus admittance matrix. Initialization, switching actions resulting in dissimilar topologies and simulation of the loss of DC lines quantity to an easy calculation or recalculation of the DC bus admission matrix. The model is implemented in Matlab. Examples on a two- and six-terminal system show that the new model is indeed capable of precisely simulating VSC MTDC systems with chance topology. In case of CSC HVDC, this would be understandable since topologies are limited to a few plain configurations anyhow, due to the inherent difficulty connected with extend CSCs to multi-terminal systems.

In [3] Javier Renedo, Aurelio Garc´ıa-Cerrada, Luis Rouco et al presents Multi-terminal High Voltage Direct Current (HVDC) using Voltage Source Converters (VSC-HVDC) is a talented technology which provides flexible control of active and reactive power and facilitates distant renewable energy integration, above all using long cables. This paper analysis an energetic power control approach for multi-terminal VSC-HVDC systems tailored to improve transient stability of hybrid AC/DC grids. The planned strategy controls each VSC using frequency measurements of all terminals. Its performance is compared to a strategy in which each VSC is controlled using only local frequency measurements of the AC side; prove that the proposed strategy shows better performance, even taking into account sensible announcement delays. The paper also shows that the proposed policy normally gives alike results to those obtain when each VSC is controlled using the speed of the centre of inertia (COI). The speed of the COI is a more comprehensive and richer figure than the one planned in this paper but it is also much more composite to obtain.

In [4] Robert Eriksson et al presents the stability of an interconnected ac/dc system is affected by disturbances occurring in the system. Disturbances, such as three-phase faults, may endanger the rotor-angle constancy and, thus, the generator fall out of synchronism. The possibility of fast change of the injected powers by the multiterminal dc grid can, by proper control action, enhance this stability. This paper proposes a novel time best control approach for the injected power of multiterminal dc grids to enhance the rotor-angle stability. The controller is time optimal, since it reduces the impact of a disturbance as fast as possible, and is based on Lyapunov theory considering the nonlinear behavior. The time optimal controller is of a bang-bang type and uses wide-area measurements as feedback signals. Nonlinear simulations are run in the Nordic32 test system implemented in Power Factory/DIgSILENT with an interface to Matlab where the controller is implemented. Many well-established analysis and design techniques exist for linear time-invariant (LTI) systems, such as root-locus, Bode plot, Nyquist criterion, state-feedback, and pole placement

In [5] Alexander Fuchs, Markus Imhof, Manfred Morari et al presents The stabilization of bulky power systems using voltage-source-converter-based elevated voltage direct current (HVDC) links. Based on global power system measurements, a model predictive control (MPC) scheme manipulate the power injections of the HVDC links to damp oscillations in the ac system. The grid controller explicitly accounts for constraints and the expected future activities of the system. Different scenarios like the defeat of production, the loss of consumption and changes to the network topology are purposeful in the continental European Network of Transmission System Operators for Electricity (ENTSO-E) system. The simulations show the presentation augmentation get with a worldwide MPC-based grid controller; compare to a limited damping controller and HVDC links with constant direction values. The ac power injections at the VSC–HVDC terminals have to be manipulated vigilantly, attractive into account the principal power system dynamics and the corporeal limitations of the ac and dc mechanism.

PROPSOED SYSTEM

A coordinated control approach for the reactive-power injections of the converters of an MTDC system using, only, the frequencies measured at the VSC stations (already available for synchronization). The results will show that, with this approach, the Critical Clearing Times (CCTs) can be increased extensively. A similar global approach was presented with superior results in when scheming active power in an MTDC scheme.

BLOCK DIAGRAM

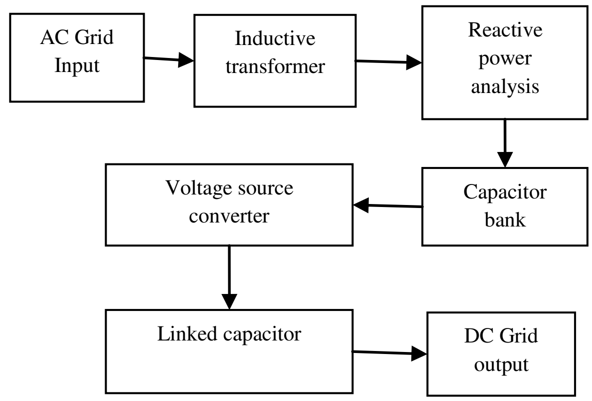


Fig 1 Block diagram

HVDC TECHNOLOGY

Even though there is an immense integer of applications in dissimilar countries LCC knowledge have show significant weakness. The commutation of the converter valves is closely associated to the stiffness of the ac voltage at the grid connection point. For that reason, the converter does operate properly at connection points with low short circuit power. The reason is that the LCC cannot create ac voltage itself. It is always necessary for the operation of the LCC that the system provides the necessary voltage. Another difficulty for the case of LCC-HVDC system is that reactive power compensation is needed. Significant amount of shunt reactive power compensation and harmonic filters are required for operation. This makes the substations large, occupying big area making LCC impractical for very compact sites. Figure 14 provides the workings and layout of an LCC-HVDC substation. In addition, the application of LCC is incomplete to one direction current flow through each converter. Hence, in order to reverse the power flow of any individual terminal the dc voltage polarity must be upturned as well. This is the major reason why LCC based HVDC technology cannot be used in applications such as multiterminal offshore HVDC networks. In a multi-terminal dc system which applies LCC technology, changing the division of the dc voltage for one dc line will modify the power flows in the network.

VSC TERMINAL MODEL

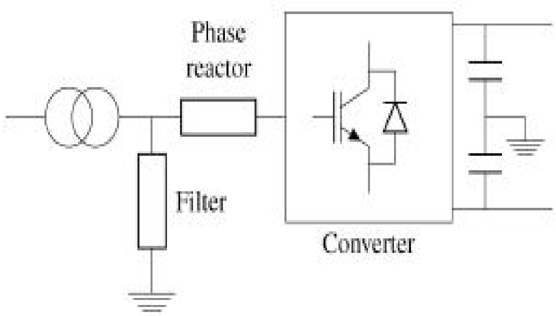


Fig 2 VSC terminal

The physical classification of a VSC-HVDC consists of a transformer on the AC side of the converter, filter, a complex inductance, VSC, a HVDC cable and an inverter on the other side of the cable. By remove the filter the calculation of converter-side voltage and power flows is simplified. Filter is important if the VSC is using reactive power for its operation. In the case of Line-Commutated HVDC the commutation is possible only with lagging current and therefore it requirements reactive power. At high powers the require for unthinking power grows as well. Therefore the AC side filter is used not only for filtering purposes but also as a reactive power compensator. On the other side filter has a considerable influence on the converter energy but not as much on power flows. Phase-locked loop (PLL) is a circuit that is synchronize output signal with a reference input signal, in frequency and phase. However, for this study we have used a beginner's VSCHVDC replica and neglected PLL.

VSC-HVDC COMPONENTS

In order to value the in commission opinion of VSC-HVDC it is significant to appreciate the components that such a system consists of. Figure demonstrates a typical VSC-HVDC system with converters, phase reactors, transformers, DC capacitors, AC filters and DC cables. These components will be describe in more detail in the subsequent sections

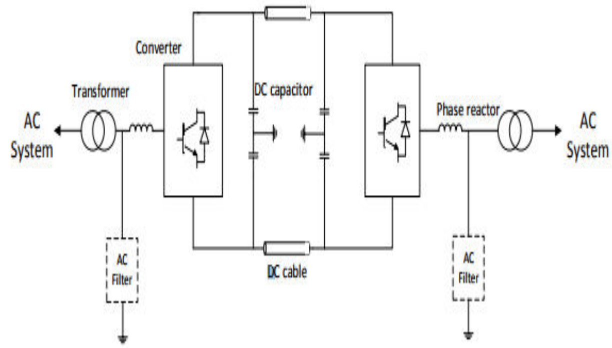


Fig 3 VSC-HVDC Components

The converter is the most important component of the VSC-HVDC system and it is used to transfer power from the AC side to the DC side when operating as a rectifier, or to inject power into the AC side operating as an inverter. It uses Pulse Width Modulation (PWM) to generate the desired voltage waveform. In this thesis, Sinusoidal Pulse Width Modulation (SPWM) is considered where the basic principle is to compare a sinusoidal control voltage to a triangular wave, also called a carrier wave. If the control signal is larger than the carrier wave, it will switch on the corresponding valve in the converter and if the control signal is smaller it will be switched off instead

VSC-HVDC TECHNOLOGY

The solution to the above problem is given by the utilization of the more recent version of HVDC technology known as the voltage source converter based high voltage direct current technology (VSC-HVDC). The development of VSC technology is based both on the improved performance and the increasing rating of the insulated gate bipolar transistors (IGBT). Also important role plays the controllability that IGBTs illustrate by means of capability to turn on and off and thus becoming a self commutated rather than line commutated converter. Furthermore, sinusoidal pulse width modulation technique (SPWM) gives flexibility and improves the performance of operation generating less harmonic distortion

With the introduction of the VSC-HVDC, there is no need to change the dc voltage polarity in order to change the dc power flows, as it is the case of LCC technology.

The last characteristic is very attractive for implementation of the VSC-HVDC at offshore dc networks. Furthermore, there is no need for reactive power compensation and no need to install large filters to suppress harmonic distortion. As a result, the converter station of VSC-HVDC is more compact in comparison to the LCC technology with beneficial effects on the construction of compact and flexible offshore station. Last but not least, with VSC-HVDC it is possible to undergo stage development of meshed ac-dc networks, with fast and cost efficient planning, construction and commissioning

PRINCIPLE OF VSC-HVDC

In principle, each VSC-HVDC converter is talented to manage active and reactive power separately by simultaneously modifiable the amplitude and phase approach of the fundamental component of the converter output voltage. The general control scheme of one VSC-HVDC converter station is shown in the Fig

The control functions of VSC-HVDC system can be classified by three control layers: system control layer, application control layer, and converter control layer as shown in Table I. The system layer controller establishes the functions for achieving bulk electric grid objectives such as power flow control, congestion management and voltage support. These objectives determine the function of the application control layer which will be discussed in the next section. The following gives a brief discussion of converter control functions.

ACTIVE-POWER CONTROL STRATEGIES

The active-power (P) injections of the converters in MTDC systems must be coordinated in order (a) to achieve the desired operating point and (b) to control the DC voltage of the HVDC grid. The DC-voltage of an MTDC system can be controlled by only one converter, the “DC slack”, or this roll can be distributed between a set of converters, using a “DC-voltage droop” strategy. The latter option seems to be more appropriate in large HVDC grids. In addition to the DC-voltage control, the active power injections of the converters can be controlled to provide ancillary services by adding additional terms to the set point of the outer controllers. The active-power set point of each converter i, with the DC-voltage droop controller and an additional supplementary reference can be written as:

$$p_{s,i}^{ref}(t) = p_{s,i}^{0} - \frac{1}{k_{dc,i}}\left(u_{dc,i}^{0} - u_{dc,i}^{t}(t)\right) + \Delta p_{s,i}^{ref}(t)$$

REACTIVE-POWER CONTROL STRATEGIES

In MTDC systems, the reactive-power (Q) injections of the converters can be controlled independently. The converters can control their Q injections or AC-voltages to constant values or, similarly to the active-power control, supplementary set points can be included in the outer control loop to provide ancillary services. In this work, Q supplementary controllers for transient stability improvement are studied. The Q set point of converter i, including its supplement, can be written as:

$$q_{s,i}^{ref}(t) = q_{s,i}^{0} + \Delta q_{s,i}^{ref}(t)$$

VSC-MTDC SYSTEM

Depending on the purpose of the study, DC cables can be modeled with distributed model or with π-circuit model. The distributed model is suitable for transient analysis, while the π-circuit model is utilized for slower dynamics. For applying the proposed control methodologies in this thesis, the π-circuit model is chosen and the fast dynamic due to the inductances of the DC cables and the switching’s of the converters are not considered in this study. The shunt DC capacitor installed in each DC bus is also included in the capacitor of the π-circuit model. Converters are responsible for injecting active power to MTDC system or extracting power from it. Different modeling approaches are presented in the literature. Two models have been used for the purpose of this thesis. In the first model, only the dynamic of the DC grid is considered and the power exchange between AC and DC are represented by DC current sources. In the second model, the AC grids are modeled as voltage sources connected to the converters. In this model, the instantaneous values of currents and voltages, in dq reference frame, are considered

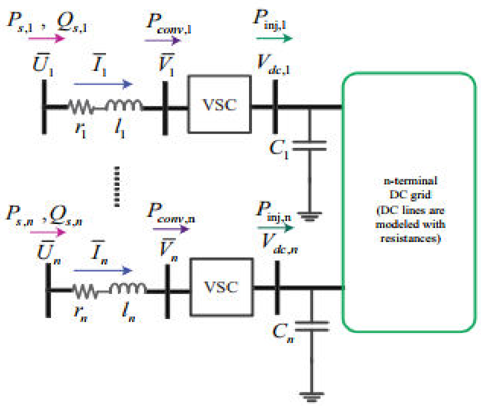
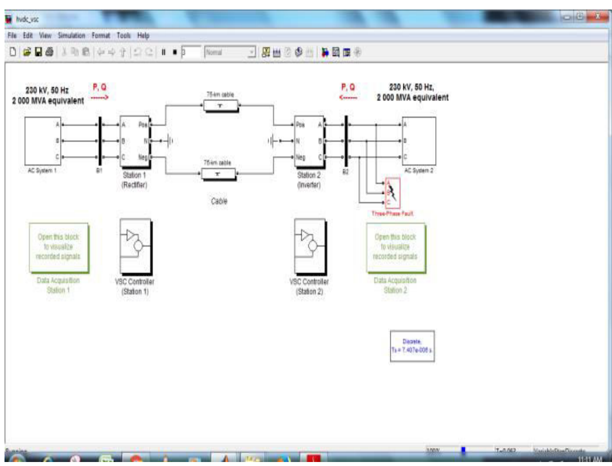


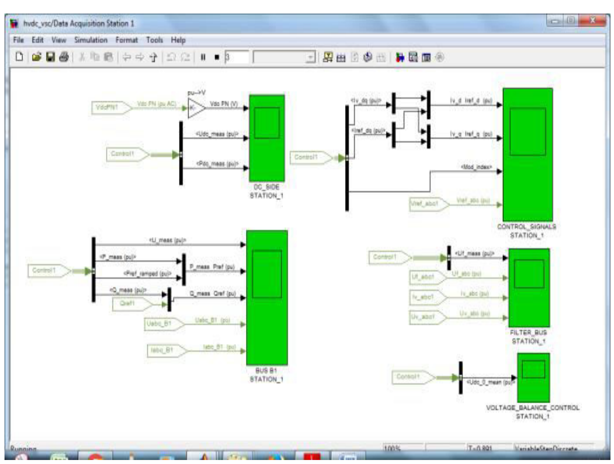
Fig 4 MTDC Grid system

OUTPUT RESULT

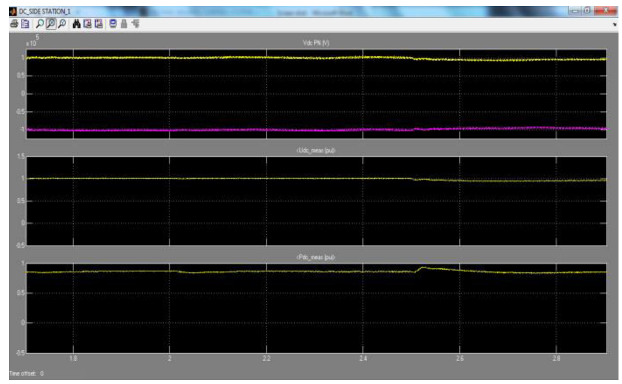
HVDC-VSC INPUT



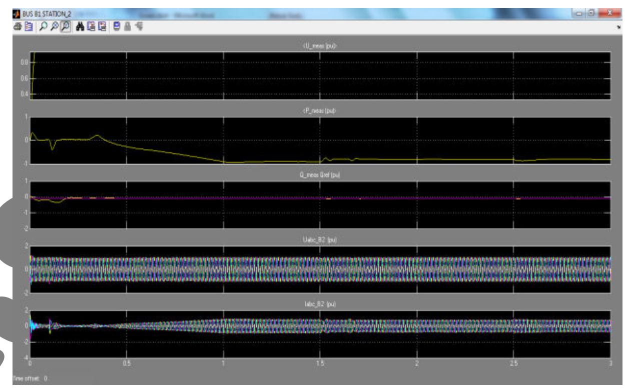
MODEL 1



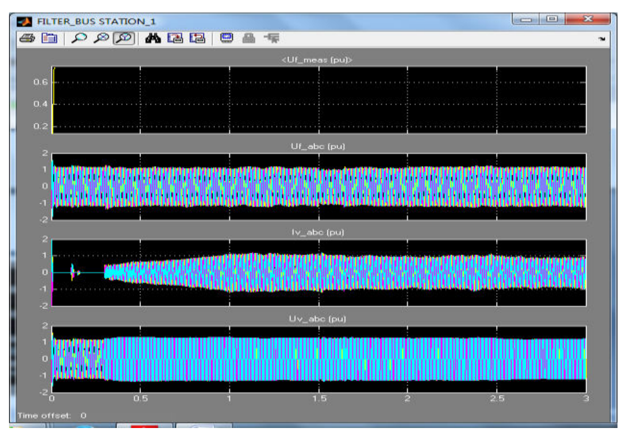
OUTPUT



TRANSIENT STABILITY MODEL



FILTER OUTPUT



CONCLUSION

A reactive-power control strategy of a VSCHVDC multi-terminal system for transient stability improvement in power systems has been proposed and analyzed. It consists in a proportional control scheme which uses the weighted-average frequency at the MTDC system converters as the frequency set-point value. Each VSC station would inject (absorb) reactive power if the frequency at its terminals is above (below) the reference value. The paper includes full description of the proposal, a simplified theoretical analysis using a Lyapunov's function and detail simulation, using PSS/E, with several scenarios based on the Cigr´e Nordic 32A system with a 3-terminal MTDC system built in. In all cases the stability limit has been measured using the CCT. First of all, different-severity faults have been investigated. Secondly, the effect of the outage of one of the converters in the system has been analyzed. Thirdly, the performance of the system in an N-2 case of the original grid has been studied. The proposed control strategy has been compared with (a) no action from the MTDC system and (b) modulation based only on local frequency measurements, where communication between the converter stations is not necessary. In all cases, the proposed strategy increases CCTs (transient stability is improved) and outperforms the other strategies. Since communications between converters (or with a central controller) is required (in order to know the weighted-average frequency at each station), the effect of communication delays on the CCTs has been investigated. Although, CCTs deteriorate as delays increase, the performance of the proposed strategy is always better than the one of strategies (a) and (b) above, for realistic delay values

REFERENCE

[1] E. Bompard, G. Fulli, M. Ardelean, and M. Masera, "It's a Bird, It's a Plane, It's a... Supergrid," IEEE power & energy magazine, vol. 12, no. 2, pp. 41–50, march/april 2014

[2] D. Van Hertem and M. Ghandhari, "Multi-terminal VSC HVDC for the European supergrid: Obstacles," Renewable and Sustainable Energy Reviews, vol. 14, no. 9, pp. 3156–3163, Dec. 2010.

[3] P. Kundur, Power System Stability and Control. McGraw Hill Education, 1993.

[4] M. H. Haque and P. Kumkratug, "Application of Lyapunov stability criterion to determine the control strategy of a STATCOM," IEE Proc. Gener. Transm. Distrib., vol. 151, no. 3, pp. 415–420, 2004.

[5] M. H. Haque, "Improvement of First Swing Stability Limit by Utilizing Full Benefit of Shunt FACTS Devices," IEEE Transactions on Power Systems, vol. 19, no. 4, pp. 1894–1902, 2004.

[6] M. A. Abido, "Power system enhancement using FACTS controllers: A review," The Arabian Journal for Science and Engineering, vol. 34, no. 1B, pp. 153–172, 2009.

[7] C. W. Taylor, J. R. Mechenbier, and C. E. Matthews, "Transient Excitation Boosting at Grand Coulee Third Power Plant: Power System Application and Field Tests," IEEE Transactions on Power systems, vol. 8, no. 3, pp. 1291–1298, 1993.

[8] L. D´ıez-Maroto, "Improvement of Voltage Ride Through Capability of Synchronous Generators with Supplementary Excitation Controllers," Master thesis, Universidad Pontificia Comillas, 2013.

[9] Y. Zhou, H. Huang, Z. Xu, W. Hua, F. Yang, and S. Liu, "Widearea measurement system-based transient excitation boosting control to improve power system transient stability," IET Generation, Transmission & Distribution, vol. 9, no. 9, pp. 845–854, Apr. 2015.

[10] A. Fuchs, M. Imhof, T. Demiray, and M. Morari, "Stabilization of Large Power Systems Using VSC HVDC and Model Predictive Control," IEEE Transactions on Power Systems, vol. 29, no. 1, pp. 480–488, 2014.

[11] I. Mart´ınez Sanz, B. Chaudhuri, and G. Strbac, "Coordinated Corrective Control for Transient Stability Enhancement in Future Great Britain Transmission System," in 19th PSCC Genoa, 2016, pp. 1–7.

[12] L. Sigrist, F. Echavarren, L. Rouco, and P. Panciatici, "A fundamental study on the impact of HVDC lines on transient stability of power systems," in PowerTech Eindhoven, 2015, pp. 16.

[13] J. Machowski, P. Kacejko, L. Nogal, and M. Wancerz, "Power system stability enhancement by WAMS-based supplementary control of multiterminal

HVDC networks," Control Engineering Practice, vol. 21, no. 5, pp. 583–592, May 2013.

[14] R. Eriksson, "Coordinated Control of Multiterminal DC Grid Power Injections for Improved Rotor-Angle Stability Based on Lyapunov Theory," IEEE Transactions on Power Delivery, vol. 29, no. 4, pp. 1789– 1797, 2014.

[15] G. Tang, Z. Xu, H. Dong, and Q. Xu, "Sliding Mode Robust Control Based Active-Power Modulation of Multi-Terminal HVDC Transmissions," IEEE Transactions on Power Systems, vol. 31, no. 2, pp. 1614– 1623, 2016.

[16] J. Renedo, A. Garc´ıa-Cerrada, and L. Rouco, "Active Power Control Strategies for Transient Stability Enhancement of AC/DC Grids With VSC-HVDC Multi-Terminal Systems," IEEE Transactions on Power Systems, vol. 31, no. 6, pp. 4595–4604, 2016.

[17] S. Cole, J. Beerten, and R. Belmans, "Generalized Dynamic VSC MTDC Model for Power System Stability Studies," IEEE Trans. on Power Systems, vol. 25, no. 3, pp. 1655–1662, 2010.

[18] J. Beerten, S. Cole, and R. Belmans, "Modeling of Multi-Terminal VSC HVDC Systems With Distributed DC Voltage Control," IEEE Transactions on Power Systems, pp. 1–9, 2013.

[19] G. Daelemans, "VSC HVDC in meshed networks," Master thesis, Katholieke Universiteit Leuven, 2008.

[20] J. Beerten, S. Cole, and R. Belmans, "Generalized Steady-State VSC MTDC Model for Sequential AC / DC Power Flow Algorithms," IEEE Trans. on Power Systems, vol. 27, no. 2, pp. 821–829, 2012.