

TOPIC TITLE: Metrology for High Voltage Direct Current (HVDC)

Abstract

There is an increasing interest worldwide in the application of High Voltage Direct Current (HVDC) for electrical power transmission. The main reasons are smaller losses compared to AC transmission and the fact that most of the renewable power resources are often best captured in places far from where energy is used. Building and implementing effective national and international HVDC networks is necessary to achieve the full potential of renewable energy.

Joint Research Projects (JRPs) submitted for this topic should aim to address a series of metrological challenges (predominantly in the electrical field) that will provide essential support to ensure accurate losses measurement in HVDC stations, and fair trade between commercial parties employing the grid.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP 2008ⁱ, section on “*Grand Challenges*” related to *Energy* on pages 8 and 23.

Keywords

High voltage direct current, electricity transport, energy measurement, energy losses, power trading, electricity distribution network

Background to the Metrological Challenges

Guiding principles of the European energy and climate policy are security of supply, economic efficiency and environmental protection (include euro policy reference). Europe has set the target of generating 20% of its energy needs from renewable sources by 2020, which represents a significant increase on current levels [3,4]. In order to reach the final end users, energy generated from these renewable sources has to be fed into the energy transmission network. The best locations for renewable energy sources as wind, geothermal, solar power, hydro power are not always close to the major energy loads of the grid, which normally coincide with the significant population clusters across Europe, for example concentrated solar power is far way from the major cities in Europe. Therefore it is necessary to transport electrical energy with low losses over large distances.

In general electrical energy (most of which is generated from conventional sources) is currently transported by means of an AC distribution network across Europe. High voltage direct current transmission is becoming increasingly important in Europe due to its smaller losses compared to AC, in particular due to the need to transport the energy generated from renewable energy sources over long distances to reach consumers [5]. HVDC technology now appears to be the

only alternative to the AC technology used previously for long distance transmission. Furthermore HVDC transmission technology is being integrated into existing closely meshed AC networks and incorporated into electricity trading. Current development is focusing increasingly on a DC network that is overlaid on top of the AC grid to transport bulk power [3,4]. This results in fewer nodes than in the AC grid and the environmental impact is smaller than for AC overhead lines.

At present, however, technical capability to measure energy flow is limited, whether in a meshed AC network or in a DC network (the voltages of modern HVDC lines are around 600 - 1000 kV DC, whilst the current maximum measurement capability in Europe is limited to 400 kV DC). The measuring systems used to date have an accuracy of 1 %.

Converter stations are used with HVDC to rectify from AC to DC and/or invert from DC to AC such that HVDC links can be incorporated with the existing AC grid system. These converter stations are in practice substantial engineering projects that require huge capital investments. Measuring the losses at converter stations requires measurements to be made of the energy transferred between the AC and DC sides of the converter stations and the energy subsequently transferred to the DC transmission link. The difference between the two figures represents the loss at the converter station. For the converter stations, losses of between 0.8 % and 1.7 % are quoted [4,6], which are difficult to prove in view of the uncertainty of the measurement. In a meshed DC network the power flows must be precisely determined within the nodes and connections to the AC network.

The power lost in the HVDC valves represents a significant amount in the balance of overall power transmission efficiency. Hydro-Québec Research Institute (IREQ) has developed a laboratory scale valve losses measurement method [7], however this method needs to be upgraded to be used in the modern high power HVDC stations and it is also necessary to develop an improved calculation methodology that will give more accurate results. Power losses of the converter valves dissipated during factory tests are not necessarily equal to losses of the valves in service.

There are two areas of application for the measurement of losses incurred in HVDC transmission:

1. Measuring the losses at the components used, as an aid to decision-making when expanding the network – also to aid the iterative improvement of designs of these components/valves/solid state systems and hence reducing future system losses.
2. Developing a system to measure data for billing and energy flow monitoring purposes when transmitting energy in a meshed AC network and DC network.

Whilst considerably better than AC transmission over long distance, the energy loss in HVDC systems is still a considerable cost in terms of revenue and Green House gas emissions. The total loss of one converter substation of the Voltage Source Converter (VSC) HVDC transmission is about 1.6% of the whole transfer on full load operation and is about 0.2% on no load or standby operation. Around 2/3 of the losses of whole substation derive from converter valves, and the rest from converter transformer, converter reactor and the other equipment [8]. Losses arising during network operation are attributed to network losses and billed via network usage fees. The latter in turn are dependent on the energy transported via the networks. With 50 GW of power to be transported, current HDVC transport losses would be around 2 GW, equating to a cost of about 0.5 billion euros. The comparable figures for AC technology would be higher.

In view of the above, a measuring system needs to be developed to determine the losses between the AC and DC sides of a converter station and over the entire DC transmission path. By specifically measuring the losses in HVDC transmission, it will be possible to accurately determine network losses in transmission and thereby attribute costs as incurred and prevent

improper billing. Reliable and accurate energy measurement in the grid is key for national and European wide trading of electrical energy from renewable sources.

The rectification and inversion of electricity involves power electronic equipment that represents a non-linear load on the electricity system. This gives rise to the generation of harmonics in the grid system. The conversion of DC to AC and the subsequent synchronization to the system frequency can lead to further system distortion. The need to measure and mitigate the power quality associated with HVDC converter systems needs to be developed and implemented.

Scientific and Technological Objectives

Proposers should aim to address all of the stated objectives below. However where this is not feasible (i.e. due to budgetary or scientific / technical constraints) this should be clearly stated in the JRP protocol. The objectives are based around the PRT submissions from various institutes. As experts in the field, JRP proposers should establish the current state of the art, which may lead to amendments to the objectives - these should be justified in the JRP proposal.

The overall scientific and technological objective is to develop crucial metrological capabilities required for successful implementation of HVDC in Europe. Specifically this shall include:

- Development and validation of advanced measurement methods for power losses in HVDC stations and components
- Development of calibration capabilities for bipolar 300 – 800 kV DC voltage measurements
- Development of on-site calibration capabilities for HVDC voltage dividers and related instruments
- Systems and methods for the measurement of power quality both on the DC and AC side of HVDC converter stations
- Development of metrological methods addressing metering and billing issues

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project.

In your JRP submission please detail the impact that your proposed JRP will have on the following Directive of the European Commission:

“Promotion of the use of energy from renewable sources Directive” 2009/28/EC [2]

You should also detail other impacts of your proposed JRP as detailed in the document “Guidance for writing a JRP”

In response to the need for standardised measurement techniques you should detail how your JRP results are going to:

- feed into the development of documentary standards and guidelines through CEN, other standards developing bodies or other appropriate bodies
- transfer knowledge to the power transmission and generation industry, regulators and policy makers.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

- [1] http://ec.europa.eu/energy/renewables/index_en.htm
- [2] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF>
- [3] Asplund, G. (2009): HVDC grids – possibilities and challenges. In: Cigré SC B4 2009 Bergen Colloquium; Paper 403. 2009
- [4] Andersen, B.; Zavaahir, M. (2009): Overview of HVDC and FACTS. In: Cigré SC B4 2009 Bergen Colloquium. 2009
- [5] See the Desertec website (www.desertec.org) for an example of a European supergrid based on HVDC, linking the optimal locations of different renewable energy sources.
- [6] Verboomen, J., Kling, WL, Hertem, D van, Cole, S & Belmans, R (2007): Influence of Phase Shifting Transformers and HVDC on Power System Losses. In: S.N. (Ed.), IEEE Power Engineering Society General Meeting. 2007 (pp. 1-8).
- [7] J. Pan, R. Nuqui, L. Tang and P. Holmberg (2008) VSC-HVDC Control and Application in Meshed AC Networks. IEEE-PES General meeting, Pittsburgh, Pennsylvania, 2008
- [8] H. Pang, G. Tang and Z. He (2008): Evaluation of losses in VSC-HVDC Transmission System. IEEE Power and Energy Society General Meeting, Conversion and Delivery of electrical Energy in the 21st century, 2008.

ⁱ European Metrology Research Programme. Outline 2008 Edition - November 2008
http://www.euramet.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/docs/EMRP-outline2008.pdf&t=1248796946&hash=9da9ceb781370f04c322ac48068deca5