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TECHNICAL REPORT

colour inside

Guideline for planning of HVDC systems – Part 1: HVDC systems with line-commutated converters

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CONTENTS

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GUIDELINE FOR PLANNING OF HVDC SYSTEMS –

Part 1: HVDC systems with line-commutated converters

FOREWORD

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IEC TR 63179-1, which is a Technical Report, has been prepared by IEC technical committee 115: High Voltage Direct Current (HVDC) transmission for DC voltages above 100 kV.

The text of this Technical Report is based on the following documents:

Draft TR	Report on voting
115/216/DTR	115/230/RVDTR

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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GUIDELINE FOR PLANNING OF HVDC SYSTEMS –

Part 1: HVDC systems with line-commutated converters

1 Scope

This document provides guidelines for the selection of a high-voltage directive current (HVDC) system with line-commutated converters (LCC), hereafter referred to as HVDC system, for the purposes of HVDC system planning. It covers the guidelines on the requirements for integrating HVDC systems in AC power networks, selection of rated voltage and power, overloads, circuit configuration, expandability, comparison of technical, economic, regulatory, political, social and environmental factors, etc. This document is applicable for planning an HVDC system.

This guideline is not exhaustive and it is possible that there will be other specific aspects, particular to a specific HVDC project, which will also need to be considered.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60633, *High-voltage direct current (HVDC) transmission – Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60633 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org
- ISO Online browsing platform: available at http://www.iso.org/obp

4 General

The HVDC system development and integration cycle may be described in terms of six phases, as shown in Figure 1.

The main task of HVDC system planning is to develop and select an HVDC scheme based on the conclusions of power network development planning where the network requirements are defined. HVDC system planning uses as a minimum the total transmission capacity and range of connection points previously determined by power network development planning, taking into account current and future conditions of the power system, environment, and other contributing factors.

There is a certain degree of repetition and iteration between HVDC system planning and system design (refer to Figure 1). For the purpose of project feasibility study and scheme comparison, some investigation would be carried out during the system planning phase, the detailed studies and final design would be accomplished during the system design phase.

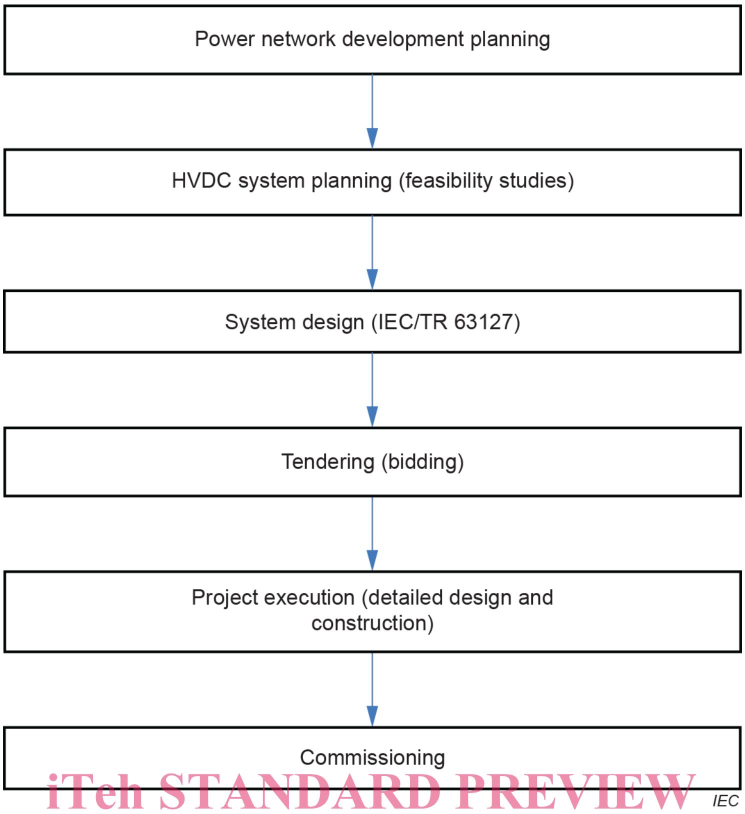

Figure 1 – Phases during integration of a new HVDC system into the power network

The work contents and procedure for planning of an HVDC system are as follows:

a) compare HVDC and AC solutions at high level according to the specific requirements (see Clause 5);

b) when HVDC is the only technically feasible solution, or the use of an HVDC scheme has overwhelming advantages, a number of alternative HVDC solutions could be investigated (see Clause 6). When both HVDC and AC alternatives are technically feasible and neither of them has overwhelming advantages, further analysis is required to confirm the preferred solution;

c) verify the security of supply and stability of each alternative (see Clause 7);

d) compare the economic efficiency of alternative solutions (see Clause 8);

e) present the recommended solution (see Clause 9).

The above steps in the planning of an HVDC system are shown in Figure 2.

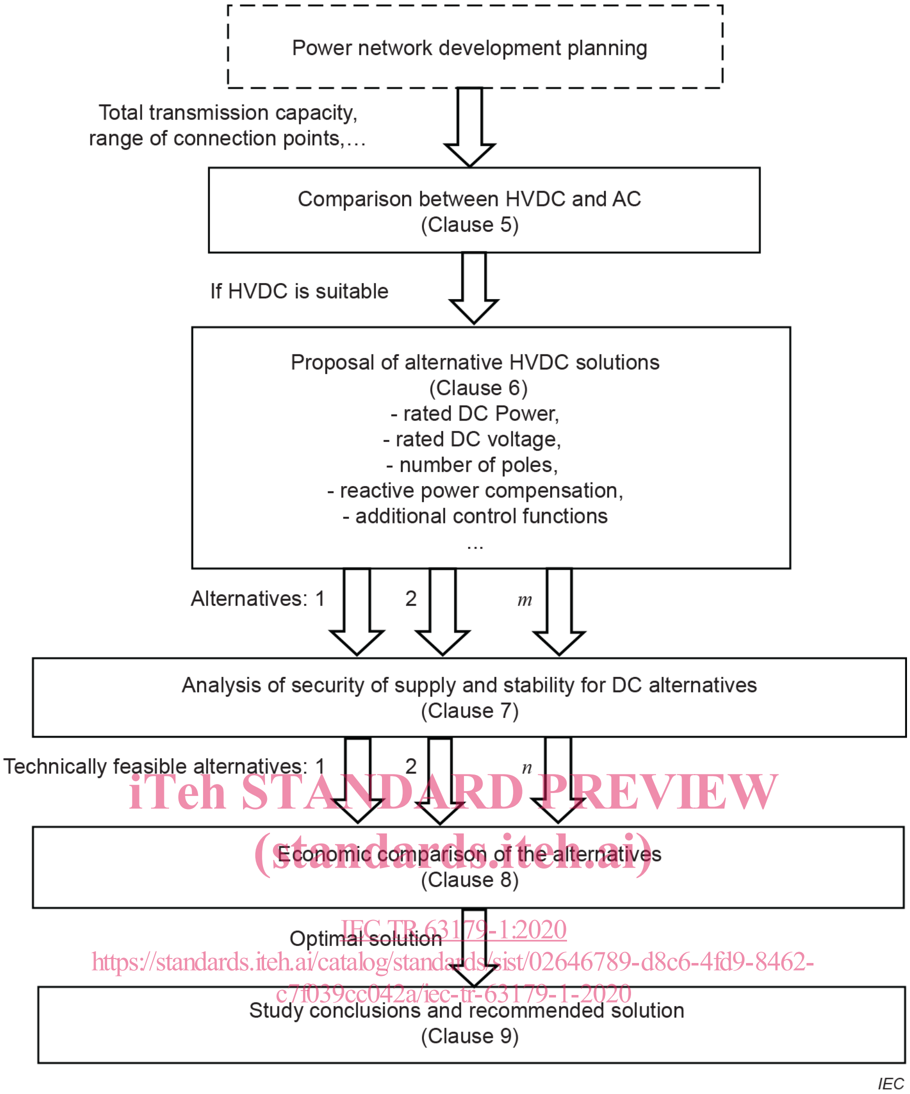

Figure 2 – Procedure for planning an HVDC system

5 Comparison between HVDC and AC alternatives

5.1 Consideration of overall network planning

5.1.1 Overall network planning

When a new line between two areas is planned, the solutions should consider all aspects of transmission planning, including the current and future power demand, line corridor conditions, operation and maintenance, energy dispatch and overall cost.

5.1.2 Connection topologies for HVDC systems

When an HVDC system is to be added to AC power networks, there are two typical connection topologies:

a) HVDC interconnection between two asynchronous AC power networks;

b) embedded HVDC system. An embedded HVDC system is an HVDC link between two parts of the same AC synchronous transmission system.

In addition, a multi-terminal HVDC link could also be considered both in a) and b) above.

5.2 Comparison of transmission capacity

The power transfer between two networks through an AC overhead transmission line is approximately given by the following expression:

$$P = \frac{V_S V_R}{X_{SR}} \sin\theta_{SR}$$

where

V_S and V_R are the voltages at the sending and receiving ends, respectively;

X_{SR} is the series reactance between the two ends;

θ_{SR} is the load angle (phase difference between the two voltages).

To ensure that synchronism between the two networks is maintained following major disturbances, the load angle is kept low during steady state operation. As a result, the power transfer capability of the AC line is reduced compared to its thermal capability. This problem does not exist with an HVDC system, as the two networks are decoupled and the power can be independently controlled by the HVDC system.

For high-voltage AC cable transmission over certain distances, the charging current becomes a major contributor to the thermal loading of the cable, due to its large shunt capacitance. This therefore limits the useful load that the AC transmission circuit can carry. With DC transmission, no charging current problems occur and therefore the useful load is also generally only limited by the thermal capability of the cable.

5.3 Comparison of operation requirements

5.3.1 Comparison of system fault and stability

Faults causing significant voltage variation or power swings do not transmit across an HVDC link. They may emerge on the other end of an HVDC link simply as a reduction in power, without causing severe disturbance on the other end of the HVDC link.

Contrary to AC transmission, HVDC does not significantly increase the short-circuit currents in both sending and receiving ends of AC power networks.

An HVDC link does not suffer from the power angle stability problems which frequently occur with long AC transmission lines. Also, an AC transmission line is sensitive to disturbances of the power balance in AC power networks, and the power flow within connecting AC lines is not easy to be controlled, whereas the controllability of an HVDC system can be used to support the stability of the connected AC networks by power runback or runup. Furthermore, an HVDC link can provide additional benefits, such as possible overload and reduced voltage operation. However, for a short time during a transient, an AC line may be able to transmit more power than a DC link, even beyond its steady state thermal capacity, while the transient overload allowed by the converter stations is usually smaller.

5.3.2 Comparison of voltage regulation and reactive power compensation

An AC transmission line imposes a load-dependent reactive power demand which may impact the active current rating, and may require reactive power compensation at the terminals, and at points along the line, to ensure the desired voltage level and adequate active power transfer capability. While series or shunt compensation can assist transmission through overhead lines, a technical limit is encountered in the case of transmission through insulated cables. Even at relatively short distances, the reactive power consumes the greater part of the current carrying capacity of the cable. Such solutions are possible, but inconvenient.

HVDC systems do not need this type of compensation and therefore do not present the same technical limitations in long transmission distance, with no requirement for special compensation along the line/cable.

5.4 Comparison of cost

The listed items below should be evaluated and compared from a monetary point of view:

a) station costs;

b) line costs;

c) cost due to the adaptation of the existing network;

d) capitalised cost of converter station and DC line losses during the life of the project;

e) operational costs;

f) maintenance costs;

g) decommissioning costs;

h) land acquisition and rights of way.

NOTE The above list is not exhaustive.

For bulk power transfer over long distances, an HVDC transmission project has a lower cost, whereas an AC transmission project has a lower cost at short distance to transmit the same power. There exists a "breakeven distance" at which HVDC and AC transmission projects have the same cost.

The comparison is shown in Figure 3. Many factors contribute to the cost of AC and DC transmission, including ratings, locations, terrain, losses, etc., therefore the determination of the actual breakeven distance for a particular transmission system should be carried out on a case-by-case basis. The breakeven distance of overhead line is typically around 600 km to 800 km. For transmission by submarine cable the breakeven distance is around 40 km to 120 km. It may not be practical to consider AC cables longer than 40 km without some forms of additional compensation measures, but HVDC links using cables over hundreds of kilometres are feasible.