Electric Power Systems Research 151 (2017) 419–431

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Review

Review of investment model cost parameters for VSC HVDC transmission infrastructure

Philipp Härtel[a,*], Til Kristian Vrana[b], Tobias Hennig[a], Michael von Bonin[a], Edwin Jan Wiggelinkhuizen[c], Frans D.J. Nieuwenhout[c]

[a] Fraunhofer IWES, Kassel, Germany
[b] SINTEF Energi, Trondheim, Norway
[c] ECN, Petten, The Netherlands

ARTICLE INFO

Article history:
Received 15 December 2016
Received in revised form 10 May 2017
Accepted 11 June 2017

Keywords:
Offshore grids
Transmission expansion planning
Cost model
HVDC
VSC

ABSTRACT

Cost parameters for VSC HVDC transmission infrastructure have been gathered from an extensive collection of techno-economic sources. These cost parameter sets have been converted to a common format, based on a linear investment cost model depending on the branch length and the power rating of cable systems and converter stations. In addition, an average parameter set was determined as the arithmetic mean of the collected parameter sets, and included in the study. The uniform format allowed for a comparison of the parameter sets with each other, which revealed large differences between the cost parameter sets. The identified disparity between the parameter sets reflects a high level of uncertainty which can only in part be explained by a varying focus and modelling approach of their sources. This implies limitations regarding the validity of the parameters sets as well as of the results from grid expansion studies carried out on the basis of these parameter sets.

Comprehensive cost reference data has been collected from realised and contracted VSC HVDC projects (back-to-back, interconnector, and offshore wind connection). The cost parameter sets have been evaluated against the reference project cost data. This evaluation has again shown large variations between the parameter sets. On average, the cost for back-to-back systems are slightly underestimated, interconnectors are overestimated, and offshore wind connections are heavily underestimated. To clearly state the validity and limitations of this comparison and evaluation, the applied methodology with its compromises and drawbacks is discussed in detail. Considering the interest in and momentum of offshore grid development, as well as the number of offshore grid investment and evaluation studies being conducted, both the availability of reliable cost reference data and the validity of investment model cost parameters need continuing attention.

Contents

* Corresponding author.
E-mail address: philipp.haertel@iwes.fraunhofer.de (P. Härtel).

http://dx.doi.org/10.1016/j.epsr.2017.06.008
0378-7796/

Nomenclature

Abbreviations

B2B	Back-to-back
ITC	Interconnector
OWC	Offshore wind connection

General

$\lceil real \rceil$	Ceiling of real ($\lceil real \rceil = \min\{n \in \mathbb{N}_0 \mid n \geq real\}$)
$\lvert set \rvert$	Cardinality of *set*

Indices and sets

$f \in F_i$	Set of branches within project i
$g \in G_i$	Set of nodes within project i
$h \in H_i$	Set of offshore nodes within project i
$i \in I_j$	Set of projects within category j
$j \in J$	Set of project categories ($J = \{\text{B2B, ITC, OWC}\}$)
$k \in K$	Set of cost parameter sets

Cost parameters and variables

B_0^k	Fixed cost for building a branch with cost parameter set k (M€)
B_{lp}^k	Length- and power-dependent cost for building a branch with cost parameter set k (M€/GW km)
B_l^k	Length-dependent cost for building a branch with cost parameter set k (M€/km)
$C_{\text{est},i}^k$	Estimated investment cost for project i (M€)
$C_{\text{ref},i}$	Reference investment cost for project i (M€)
$C_{\text{ref},i}^{\text{con}}$	Reference contracted cost for project i (M€)
N_0^k	Fixed cost for building a node with cost parameter set k (M€)
N_p^k	Power-dependent cost for building a node with cost parameter set k (M€/GW)
S_0^k	Fixed additional cost for building an offshore node with cost parameter set k (M€)
S_p^k	Power-dependent additional cost for building an offshore node with cost parameter set k (M€/GW)

Technical parameters and variables

$\hat{P}_j$	Maximum power rating for a single installation within category j (GW). In case of a back-to-back system, this is twice the system rating (two fully rated converters at one node)
$l_{\text{OHL},f}$	Overhead line section length of branch f (km)
$l_{\text{SMC},f}$	Submarine cable section length of branch f (km)
$l_{\text{UGC},f}$	Underground cable section length of branch f (km)
l_f	Total equivalent line length of branch f (km)
p_f	Installed power rating of branch f (GW)
$p_{g/h}$	Installed power rating at node g/h (GW). In case of a back-to-back system, this is twice the system rating (two fully rated converters at one node)

Deviations and errors

D_i^k	Project investment cost estimation deviation of project i for cost parameter set k (–)
D_j^k	Category investment cost estimation deviation of category j for cost parameter set k (–)
E^k	Overall investment cost estimation error for cost parameter set k (–)
E_j^k	Category investment cost estimation error of category j for cost parameter set k (–)

1. Introduction

Many transmission expansion studies have investigated and optimised the topology of a future North Sea Offshore Network [1]. A solid cost parameter basis, serving as input for the optimisation algorithms, is crucial to producing reliable results in investment planning. As with offshore wind investment cost [2], these types of cost parameters have been widely used by academia and policymakers for assessments and decision support. However, the cost parameters of offshore transmission infrastructure show significant variations from study to study and indicate a high level of uncertainty. Clearly, and also in light of scientific standards, this calls for a cautious and transparent attempt to compare previously used cost parameter sets and evaluate them against real project cost