A Techno-Economic MILP Optimization of Multiple Offshore Wind Concessions.

S. Hardy, K. Van Brusselen
CG Holdings Belgium NV – Systems Division

D. Van Hertem, H. Ergun
KU Leuven - Department of electrical engineering

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement no. 765585.

INTRODUCTION

Building better, cheaper offshore transmission systems.

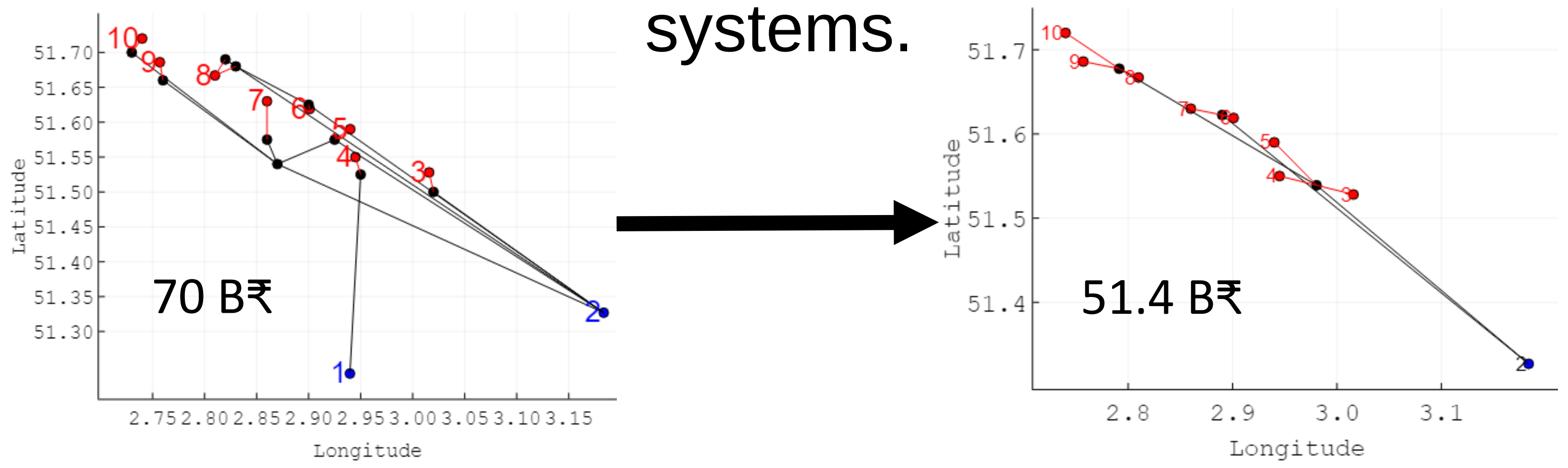


Fig. 1. The as-built (left) and optimal (right) offshore Belgian transmission grid.

Currently, the practice within the European offshore wind industry is for countries to designate an offshore wind power zone within their Exclusive Economic Area (EEA). This zone is then further divided into individual concessions which are auctioned off to developers. Developers then optimize concessions independently. As such, research on optimization of the transmission system layout has been heavily focused at the scale of the individual concession, ignoring the possible gains that come from current or future developments in neighboring concessions within the same region. There is a significant opportunity for both cost savings and increased system reliability by optimizing an entire offshore wind zone prior to the development of each individual concession. This work investigates these opportunities in the cases of the Belgian North Sea and zone ”A” as designated by the Facilitating Offshore Wind in India (FOWIND) consortium within the Bay of Cambay in Gujurat India.

METHODOLOGY

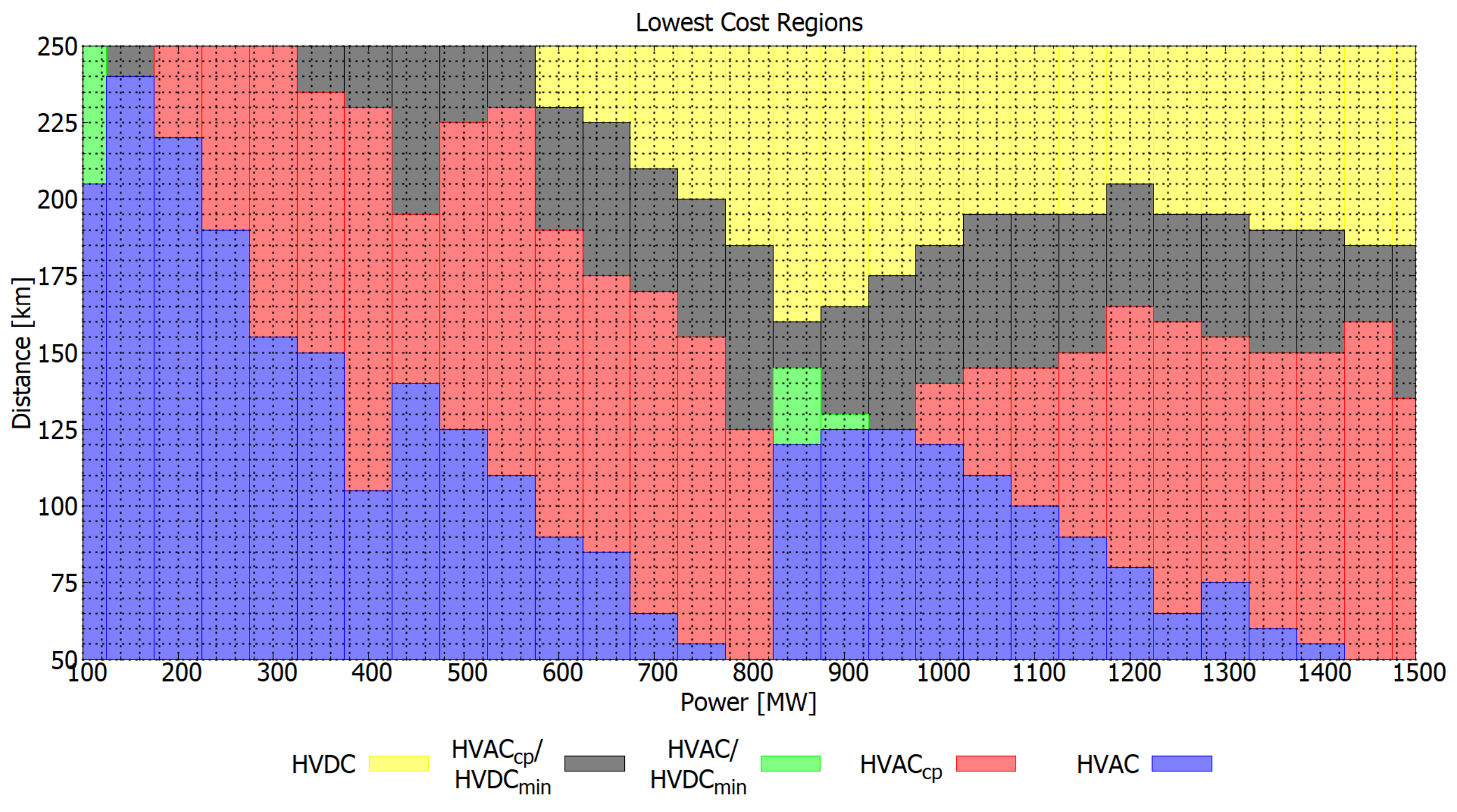


Fig. 2. Economic regions per technology.

The optimization considers both AC and DC technology as well as a number of different voltage levels for both technologies. For AC connections, the possibility of mid-point compensation has been shown to extend the economic range of HVAC systems and is as such considered in the selection of candidate submarine cables.

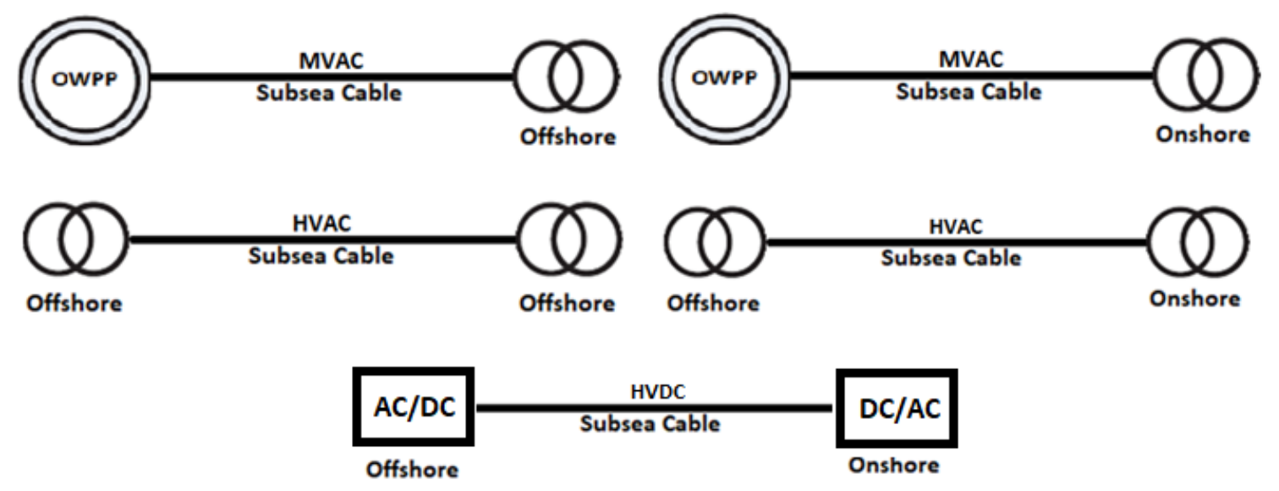


Fig. 3. Feasible connections.

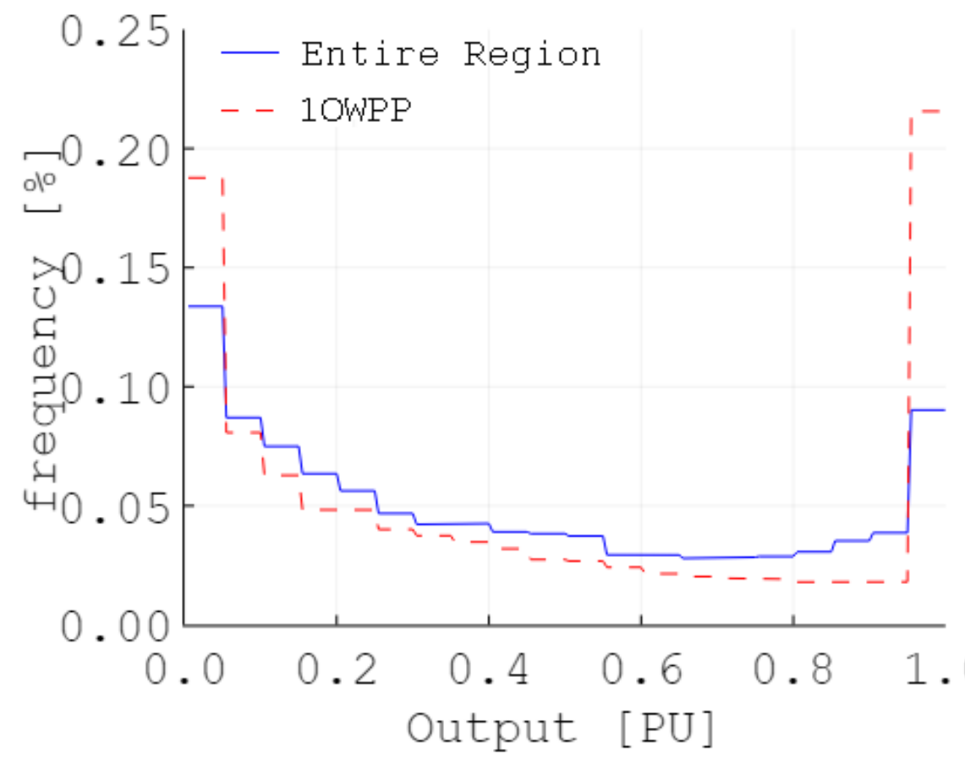
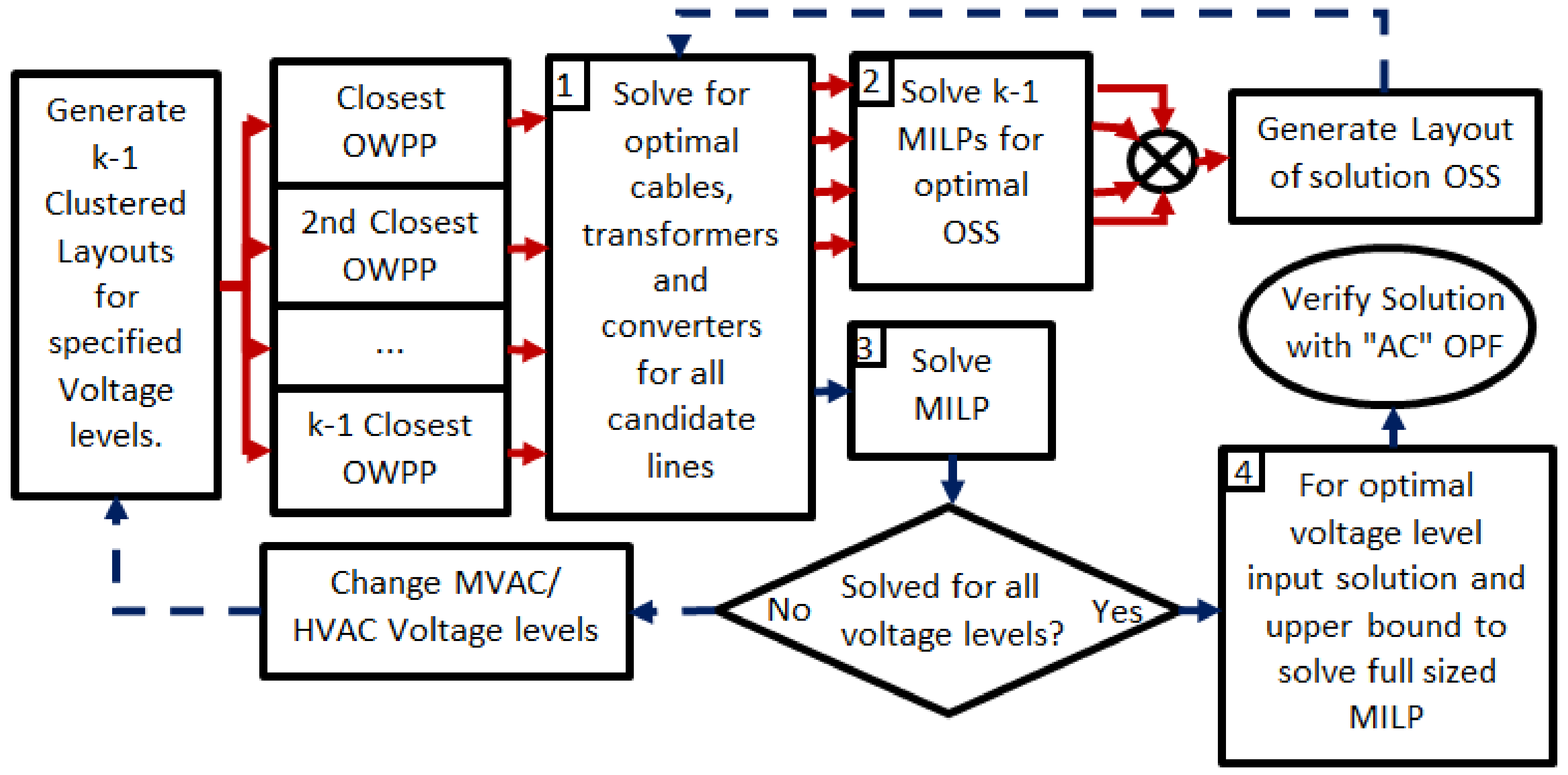


Fig. 4. Single/regional wind profiles.

For regionally meaningful results, input wind data must reflect well local conditions. To achieve this, profiles generated via the CorWind software are used. CorWind generates wind time series through a combination of meteorological reanalysis techniques and stochastic simulations.



Generate k-1 Clustered Layouts for specified Voltage levels.

Closest OWPP

2nd Closest OWPP

...

k-1 Closest OWPP

1 Solve for optimal cables, transformers and converters for all candidate lines

2 Solve k-1 MILPs for optimal OSS

Generate Layout of solution OSS

Verify Solution with "AC" OPF

3 Solve MILP

Solved for all voltage levels?

No

Change MVAC/ HVAC Voltage levels

Yes

4 For optimal voltage level input solution and upper bound to solve full sized MILP

Fig. 5. The 4 stage optimization algorithm.

The objective of the optimization is the minimization of the lifetime cost of the transmission system. The methodology employs 4 stages of optimization as shown in Fig. 3. The first 3 stages are used to select an appropriate voltage level for MVAC and HVAC networks, as well as to calculate an initial solution and upper bound for solving the full size problem. The cascading nature of the algorithm allows the best solution from the previous optimization to be introduced as an initial solution and the objective function value as a maximum upper bound in subsequent Mixed Integer Linear Programs (MILPs), which helps to reduce computational time.

RESULTS

The optimal solution in the Bay of Cambay was found to have a 66kV MVAC network and a 220kV transmission network. The total cost of the system is 258M₹. The per MW cost of the Indian transmission system at 27M₹/MW, is more expensive than that of the North Sea despite the conglomeration of a much larger area of generation. This is not a surprising result, however, as capacity factors are much lower.

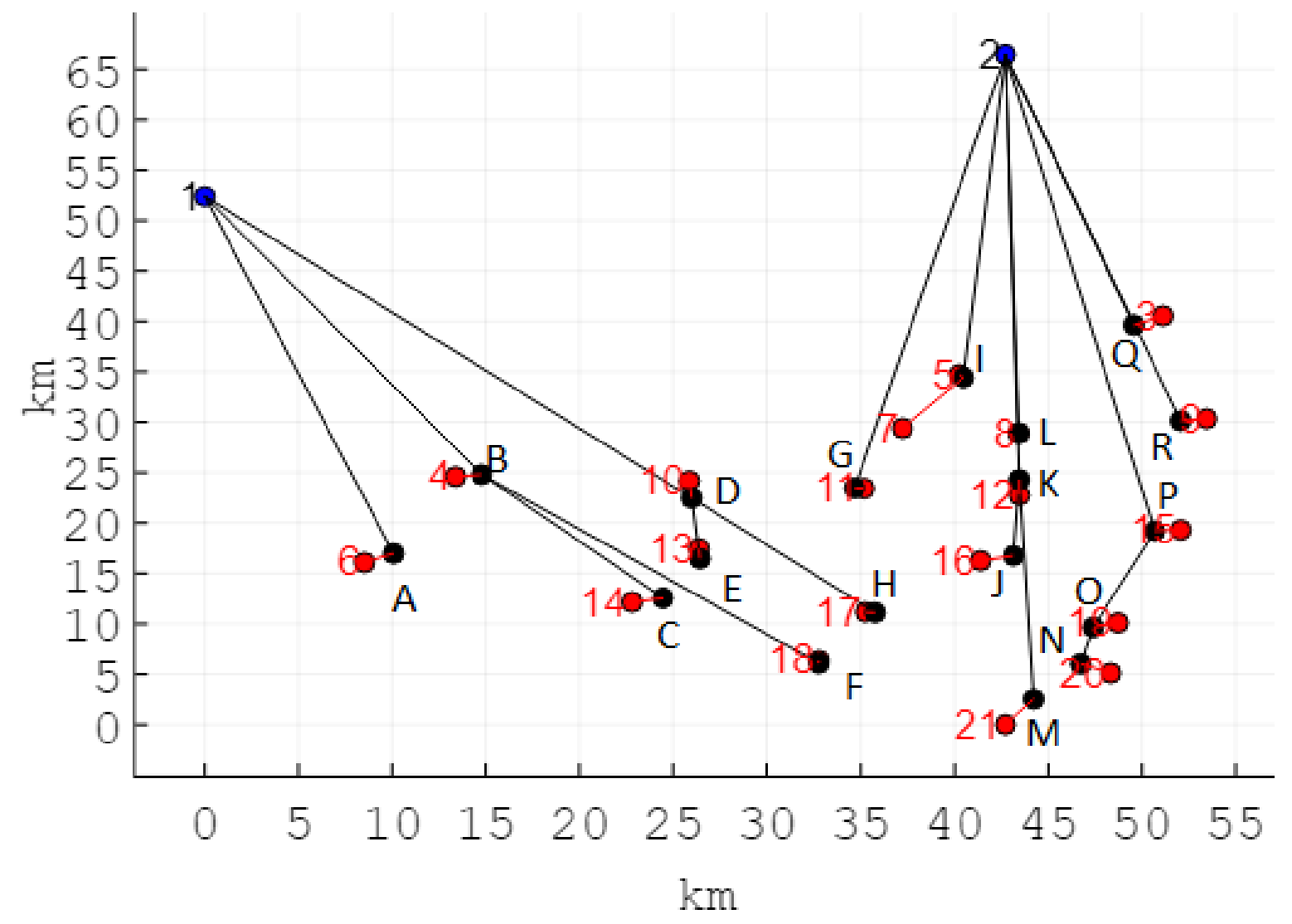


Fig. 5. The optimal offshore transmission system for Gujarat India.

Table 1. Optimal OSS locations.

OSS	Longitude	Latitude	OSS	Longitude	Latitude
A	71.1243	20.3992	J	71.4414	20.4207
B	71.1632	20.4728	K	71.4388	20.48875
C	71.2654	20.3698	L	71.435	20.53
D	71.2724	20.46	M	71.4625	20.29375
E	71.2812	20.4063	N	71.4839	20.3269
F	71.35	20.3175	O	71.4875	20.36
G	71.355	20.475	P	71.5118	20.4481
H	71.375	20.365	Q	71.4856	20.6308
I	71.4024	20.5775	R	71.5167	20.5472

Table 3. Ratings of HVAC OSS to OSS connections (CU).

Start	End	[km]	[kV]	[MVA]	Number	[mm]
O	P	10	220	1076	3	800
E	D	6	220	506	2	400
O	N	4	220	506	2	400
K	J	8	220	506	2	400
H	D	15	220	506	2	400
F	B	26	220	504	2	400
M	K	22	220	505	2	400
C	B	16	220	505	2	400

Table 2. Lengths of 66 kV connections (6-800 mm CU in parallel).

Start	End	[km]	Start	End	[km]
6	A	2	16	J	2
4	B	1	12	K	2
14	C	2	8	L	1
10	D	2	21	M	3
13	E	1	20	N	2
18	F	1	19	O	1
11	G	1	15	P	1
17	H	1	3	Q	2
5	I	1	9	R	1
7	I	6			

Table 4. Ratings of HVAC OSS to PCC connections (CU).

Start	End	[km]	[kV]	[MVA]	Number	[mm]
A	1	37	220	502	2	400
B	1	31	220	1528	5	630
D	1	40	220	1522	5	630
G	2	44	220	500	2	400
I	2	32	220	1006	3	1000
K	2	42	220	1520	5	630
L	2	38	220	502	2	400
P	2	48	220	1514	5	630
Q	2	28	220	504	2	400
R	2	37	220	502	2	400

CONCLUSIONS

I. A 26.6% savings over the existing installation in the Belgian region was found.

II.The optimal transmission voltages were 66 kV and 220 kV.

III. 66 kV MVAC connections allow for grouping of OSSs and lower cable losses.

IV. A further reduction could be obtained by adding a further optimization stage which maintains the connection topology but minimizes cable length.

V. A natural grouping appeared between OWPPs based on which PCC they are closest to. This could be leveraged in breaking down future large scale problems.