

A multi-stage methodology for wind park inter-array cabling: graph preparation, routing, and sizing

Response to Reviews

This document contains the response to the paper's reviewers ***A multi-stage methodology for wind park inter-array cabling: graph preparation, routing, and sizing***. The authors thank the reviewers and editor for their valuable suggestions. Each comment, suggestion, or recommendation was analysed in detail and answered in the context of the proposed paper. All changes in the paper were highlighted in blue and referenced in this response as a text box.

Editor:

Please address the relatively minor comments from the reviewers.

Authors' comment

The minor comments have been addressed.

1 Reviewer 1

Reviewer's Concern 1.1

Only a minor correction to line 89: "When conductor costs scale *sublinearly* with power capacity" – according to figure 3b, the correct would be "superlinearly" (the other use of "sublinear" in line 415 is correct, as it refers to figure 3a).

Authors' response 1.1

Fixed

When conductor costs scale [superlinearly](#) with power capacity and only a limited number of conductor cross-sections can be used, the shortest feasible route is not necessarily the least-cost route.

2 Reviewer 2

The manuscript has been substantially improved, but I suggest a few points are clarified before publication:

Reviewer's Concern 2.1

The authors should be careful in presenting the novelty of the work. Most of the individual modelling components are established in the literature, and the main contribution appears to be their integration in a common framework with spatial and conductor-size constraints. This is a relevant contribution, but the novelty should not be overstated.

Authors' response 2.1

We have revised the contribution statement to avoid overstating the novelty of the individual modelling components and to clarify that the main contribution lies in their integration within a common graph-preparation, routing, and CSS framework. The individual elements are now presented as components supporting this main contribution.

To address these criteria, the main contribution of this work is a graph-prepared optimisation framework for radial inter-array grids that evaluates how spatial feasibility constraints and conductor-size restrictions jointly affect routing decisions, showing that the shortest routing solution is not necessarily the least-cost solution when CSS and conductor-type limits are considered. This contribution is supported by the following components:

Reviewer's Concern 2.2

The computational benefit of the proposed reduced routing formulation should be discussed more carefully. Although it uses fewer variables, the benchmark indicates that it can be slower than the compared formulation, mainly due to the additional constraints. It would therefore be useful to clarify what the practical advantage of this formulation is.

Authors' response 2.2

We have clarified that the reduced variable representation does not necessarily reduce solution time, but provides a simpler formulation for incorporating additional routing and CSS constraints.

1 Introduction ... , showing that the shortest routing solution is not necessarily the least-cost solution when CSS and conductor-type limits are considered. This contribution is supported by the following components:

- ...
- A reduced MILP formulation for inter-array routing using a single binary variable per arc, providing a simplified representation of the routing decisions that can be extended with additional routing and CSS constraints.

7.1 Collector system routing benchmarking

The second evaluation concerns computational performance, shown in ???. The proposed methodology is slower in most cases. The explicit modelling of cable crossing restrictions

increases the number of constraints and introduces a combinatorial structure that is more difficult for the branch-and-bound algorithm to resolve. Although feasible solutions of comparable quality are identified early in the search, the LP relaxation bound is weaker than that of the planar-embedding approach, making the optimality gap more challenging to close within a given time limit. The advantage of the reduced variable representation is therefore not necessarily a reduction in solution time, but a simpler representation of each candidate connection that facilitates the incorporation of additional routing and CSS constraints. This simplification is, however, counterbalanced by the static crossing constraints.

Reviewer's Concern 2.3

The coupling between routing and conductor sizing is an important aspect of the paper, but similar integrated approaches exist in the literature. The authors should make clearer what is specifically different in their approach and what additional benefit is obtained from this coupling.

Authors' response 2.3

We have revised the contribution statement to clarify how the coupling is treated in the proposed framework. Restricting the allowable conductor set affects the maximum transferable power and number of turbines per string, directly influencing the feasible routing configuration. This is relevant as minimum-length routing does not necessarily result in minimum investment.

To address these criteria, the main contribution of this work is a graph-prepared optimisation framework for radial inter-array grids that evaluates how spatial feasibility constraints and conductor-size restrictions jointly affect routing decisions, showing that the shortest routing solution is not necessarily the least-cost solution when CSS and conductor-type limits are considered. This contribution is supported by the following components:

-
- A joint treatment of routing and conductor size selection, in which restricting the conductor types selected from the allowable set influences the feasible routing configuration through the maximum transferable power and corresponding number of turbines per string, rather than being treated only as post-processing.

Reviewer's Concern 2.4

The quantitative benchmarking mainly concerns the routing component. The limitations of the validation of the complete framework should therefore be acknowledged when drawing conclusions about its overall performance.

Authors' response 2.4

We have revised the Conclusions to acknowledge the scope of the quantitative benchmarking and the limitations in assessing the overall performance of the complete framework.

8 Conclusions

The case studies are based on existing turbine ratings and locations, encompassing both onshore and offshore scenarios. While they demonstrate the strategies' usability, they cannot be directly compared to real project deployments, as the input data used by the authors differ from those of the individual projects. In addition, the quantitative benchmarking is mainly focused on the routing stage, with the complete framework assessed through its application to the case studies. These aspects limit the extent to which its overall performance can be compared against existing approaches. In the case of the Moray developments, where a realistic representation of cable paths was publicly available, the optimisation predicted a very similar interconnection routing.

Reviewer's Concern 2.5

Finally, the sensitivity to some modelling choices, in particular big-M parameters and graph construction parameters, could be discussed briefly, as these choices may have an important effect on computational performance and solution quality.

Authors' response 2.5

We have added a brief discussion of the big- M selection in the equality constraints presentation. The influence of graph construction parameters is also discussed in the Limitations section.

4.2.1 Equality constraints

To support this linearisation, a big- M parameter is introduced to relax specific constraints involving binary variables. In this study, it is defined in Eq. (1), where M_a represents the maximum allowable power for any conductor type in branch a , scaled by a security factor κ . The value of κ is set to 1.1. This parameter acts as an upper bound, effectively deactivating flow constraints when the corresponding binary variable indicates that the conductor is not selected:

$$M_a = \kappa \cdot \max [P_{a,\iota}^{\max} \forall \iota \in \mathcal{I}]. \quad (1)$$

Importantly, M_a is defined separately for each branch to keep the big- M value as tight as possible based on the available conductor capacities. A single global big- M value could also be used, but this may introduce unnecessarily large bounds for some branches, resulting in a weaker relaxation and reduced computational performance.

7.3 Limitations

In all cases, the routing algorithm is constrained by the graph preparation process. The inclination threshold determines the viability of candidate connections, while soft-exclusion penalties modify their weights and therefore influence their selection. The level of densification further determines the spatial resolution of the graph, where higher densification can provide better-informed candidate paths at the expense of increased computational cost. Connections that may appear feasible upon visual inspection can be excluded due to cable crossing constraints, an inherent limitation of using static constraints.