Optimizing cable routes in offshore wind farms

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Offshore wind farm cabling

Motivation

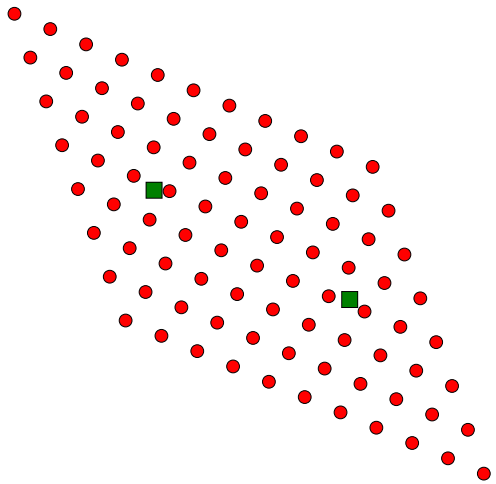
- High cabling and trenching costs offshore
- Often selected manually
- "Free" improvements by applying optimization
- Some companies (e.g. Statkraft) started using optimization methods
- Creating more advanced models, taking into consideration more aspects

Given data

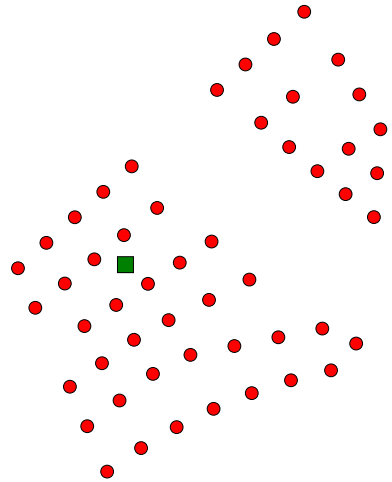
- Wind turbine positions
- Substation position(s)
- Max. energy output of turbines
- Obstacles
- (Available cable types)
- (Cable paths for comparison)

Wind farm data

- Turbine and substation position data of offshore wind farms
  - Barrow
  - Sheringham Shoal
  - Walney 1
  - Walnev 2



Sheringham Shoal



Walney 2

Problem properties

Basics

- Cable capacity
- Connectivity
  - turbines to substations
- Non-crossing

Possible additions

- Branching
- Different cable types
- Obstacles
- Parallel cables
- Energy losses

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We want to

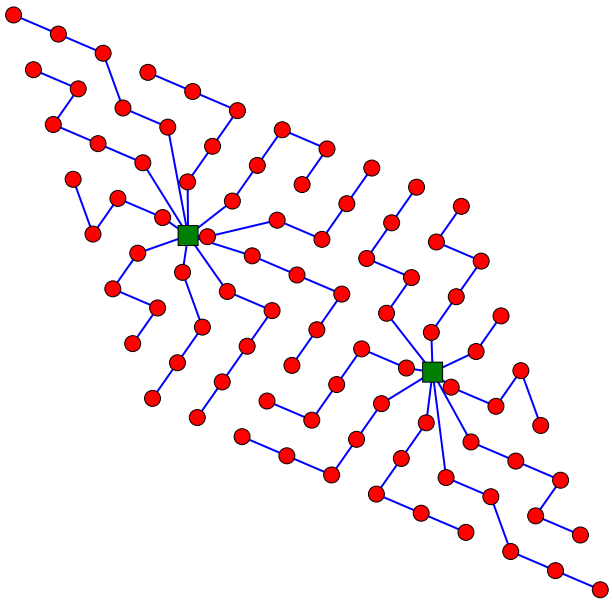
- Find optimal cable paths
- Minimize total cable length/cost
- Satisfy constraints

Optimization method and solution method

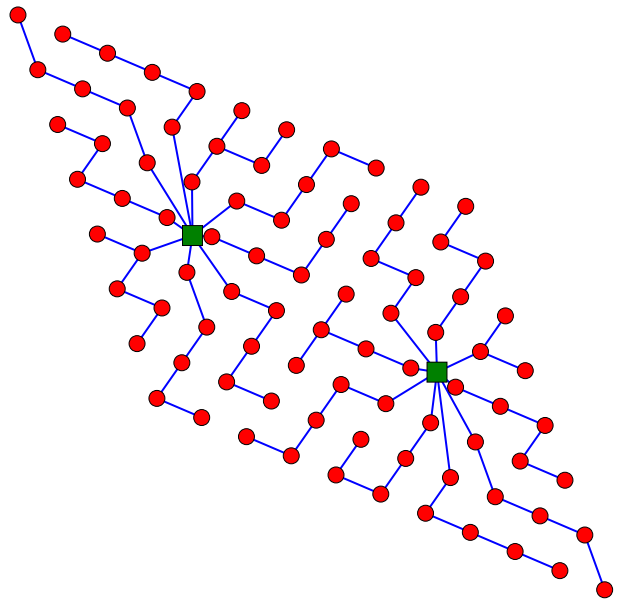
- Mathematical model describing the problem
  - Integer linear programming (ILP)
  - Linear constraints
  - Binary decision variable
  - $y_{ij} = 1$ means that there is a cable between turbine j and i
- Implemented using Python, solved by IBM CPLEX optimization library
  - Non-crossing constraints ($O(|N|^4)$) only added if solution violates them

Experimental results - one cable type

- Relative improvement from branching below 1% for all test cases
- Example Sheringham Shoal with $C = 5$
  - relative improvement 0.72%



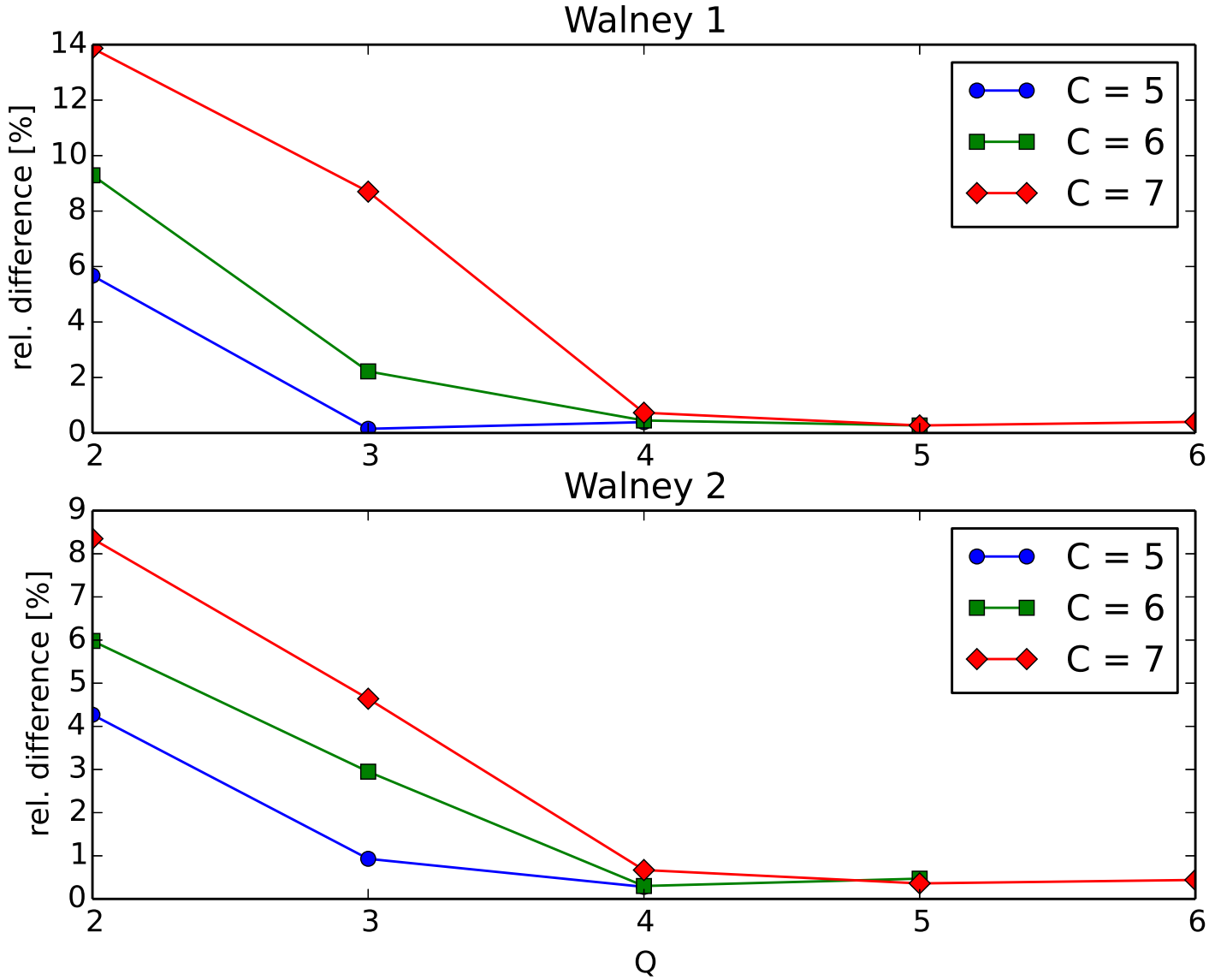
No branching



Branching

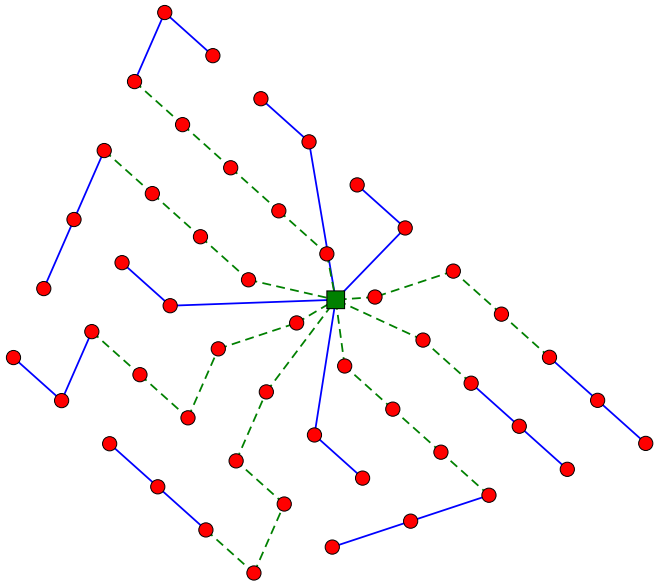
Experimental results - two cable type (1)

- Cable capacity $C > Q$, cable cost $c_{ij} = 1.7q_{ij}$

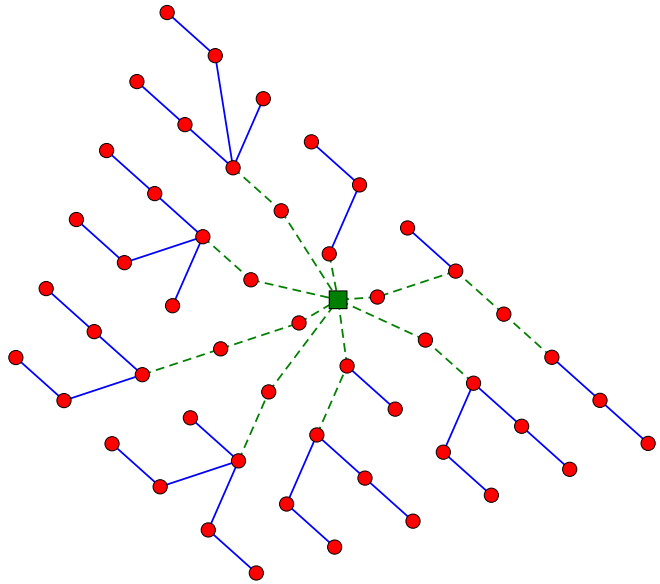


Experimental results - two cable type (2)

- Walney 1, $C = 7$, $Q = 2$

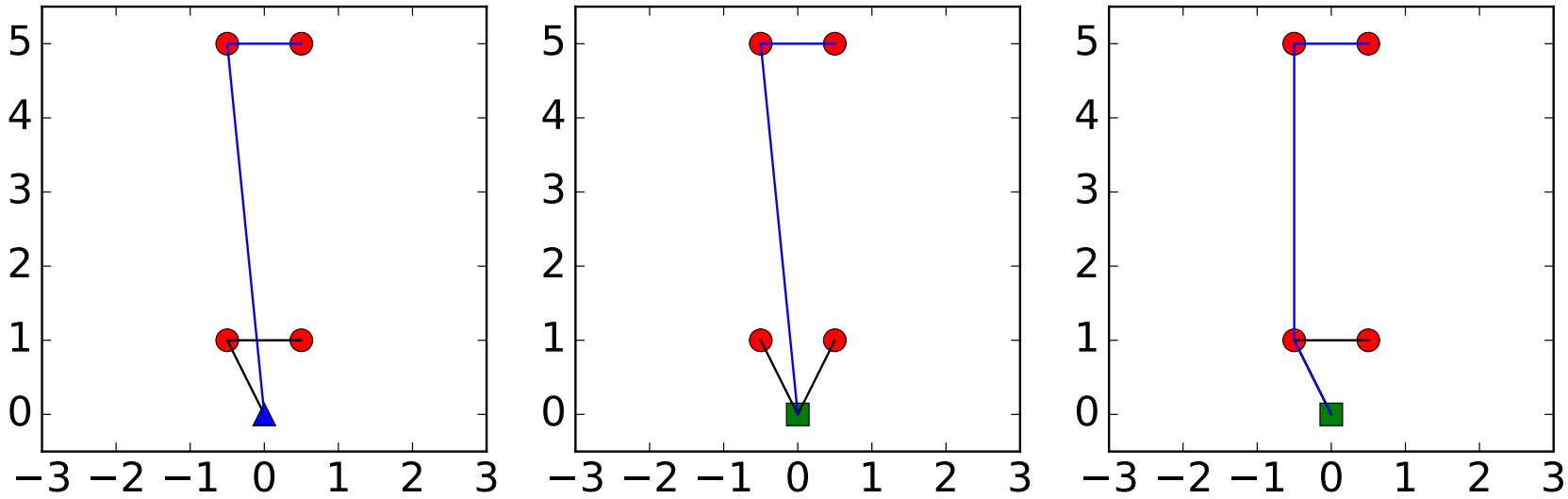


No branching



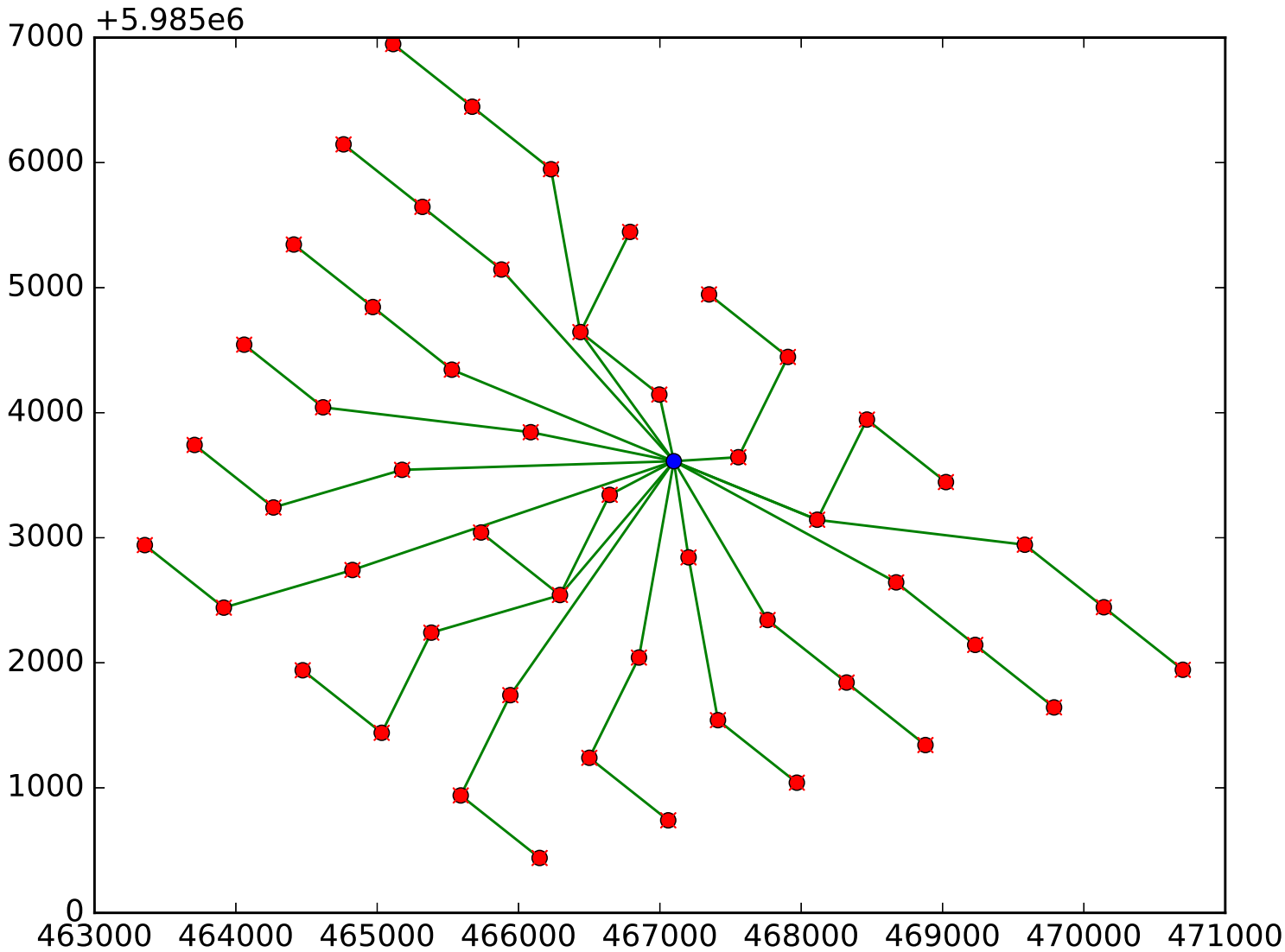
Branching

Parallel cables



- Can improve solutions in some special cases
- Same mechanism in model allows to handle obstacles better

Parallel cables example, Walney 1



Challenges

- Does not scale well with number of nodes
- High computational costs
- Information on cable cost hard to obtain

Thank you!