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Optimization of offshore wind farms with HVDC transmission network

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Recently, offshore wind farms have attracted more and more attention because of their greater energy capacity. To obtain the best performance from a wind farm, a technical and economic compromise between energy efficiency and overall investment must be established. The exploitation of this energy requires investments in the transmission of energy to the terrestrial network. Nevertheless, it is important to consider cheaper transmission solutions with less energy loss. There are two main technologies for alternative or continuous network transmission: HVAC and HVDC. In fact, HVAC is the most economic connection solution for short transmission distances and HVDC transmission method provides more advantages for distances exceed 100-150km [1].

In this article, a study was carried out on the Borssele I & II offshore wind farm [2] with an AC distribution network and a HVDC transmission network. Optimization is done by the genetic and Prim algorithms. The genetic algorithm is used to provide the first topologies of connections such as the connection between wind turbines and the connection between offshore substations as well as their positions and Prim algorithm is used to complete the connection between each group of wind turbines and the nearest substation [3]. The objective function posed is the Levelized Production Cost (LPC (c€/kWh)) which is the ratio between the total investment cost and the energy delivered to the terrestrial network grid presented by the equation (1).

$$LPC = \frac{C_{invest}}{E_d} \tag{1}$$

With: $$C_{invest} = \frac{r(1+r)^T T}{(1+r)^T - 1} \frac{1}{1\text{-}\mathrm{PR}} C_0 \tag{2}$$

$$E_d = P_{sortie} N_t T = [(n_{eol} P_{eol}) - P_{pertes} - P_L] N_t T \tag{3}$$

Where C_0: total initial investment, T: offshore wind farm lifetime set at 20 years, r: bank interest rate of 4%, PR: banks profit 2%, n_{eol}: number of wind turbines, P_{eol}: wind turbine power, P_{pertes}: power losses, P_L: total active power consumed, N_t= 365.24 (number of hours of wind farm operation per year).

For the calculation of the AC/DC load flow, the sequential method is used. It consists in calculating the state variables of the AC and DC systems and iterating them one by one, until all state variables converge. During this process, the AC energy flow equations and the DC equations are solved separately. The power flow calculation is provided by MatAC/DC [4] which takes also into consideration the mode of control of converters. Borssele I & II contains 116 turbines each producing 6 MW, a maximum of 4 substations are fixed and its positions are variable. The losses are divided in three categories: transmission losses (HV network), converters losses and distribution losses (MV network). Q_{dc} are the reactive losses for the distribution network. The figure below shows the topology of Borssele I & II park obtained with optimization.

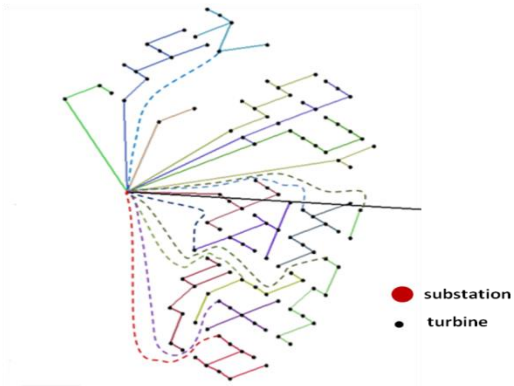

Figure 1. Borssele I & II topology obtained with optimization.

The results found with a transmission distance equal to 140 km are: $P_{dc}=L_{transHV}+ L_{conv}+ L_{distrMV}= 9.15+22.96+ 12.269 = 44.37$ MW and $Q_{dc}= 112.15$ MVAR. The results showed the presence of a single substation. In the article, a detailed study of power flow calculation and the different mode of control of converters are presented to highlight the impact of HVDC transport for large transmission distances.

Références

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