Large Scale Electricity Storage On Energy Island

Frits Verheij (KEMA, Arnhem, Netherlands) frits.verheij@kema.com); Wouter de Boer (KEMA); Albert Quist (Bureau Lievense)

Electricity storage and offshore wind energy is an excellent combination. The temporary storage of electricity is a well-established practice. Good results have been achieved with pumped storage facilities in several countries, e.g. Germany, Austria, Norway, the UK and the USA. In the Netherlands, too, electricity storage is attracting increasing attention.

Electricity storage offers considerable added value for the energy sector. It increases the technical reliability of the power supply, stabilizes the cost of electricity and helps to reduce CO_2 emissions. The integration of electricity storage within the power supply system has numerous environmental benefits, particularly if storage is combined with wind-powered generating capacity on a large scale. For example, the storage system enables the capture of electricity produced by wind farmr in periods of low loads (at night). This way there is less need to shut down wind farms nor conventional power plants during these periods.. During the daytime, stored electricity can be utilized, thus doing away with the need to deploy additional peak-load plants. This reduces the overall amount of CO_2 associated with electricity production and increases the energetic efficiency of the conventional power plants. Furthermore, the storage system can be employed for regulating power in order to increase the reliability of the electricity production also in the case of strong variations due to wind energy. Last but not least, investment in large-scale storage can substitute for investment in the replacement or new development of peak production capacity.

The Dutch energy consulting company KEMA and engineering firm Bureau Lievense have been working to take advantage of this situation. A preliminary design has been produced for an artificial ‘energy island’ – an innovative concept for large-scale energy storage – off the Dutch coast. The benefits of creating such an island would be long-lasting and not confined to the energy sector: it could provide coastal protection, harbor facilities, aquatic biomass and tourism opportunities. On behalf of a number of dutch (or dutch-based) utilities and TSO TenneT, KEMA and Bureau Lievense have investigated the technical feasibility and economic viability of large-scale offshore electricity storage. A study was performed, in which storage on an energy island – a pumped accumulation system (PAC) using a lake laying below sea level (‘inner lake’) – was compared with compressed air energy storage (CAES) and with an increase in the capacity of the high voltage interconnector between the Netherlands and Norway using Norway’s hydro power plants as a storage system.

The energy island concept is as follows. An artificial island would be created, incorporating a pumped energy storage facility that reverses the principle on which a conventional PAC facility works. When the supply of electricity exceeds demand, seawater is pumped out of the lake enclosed within the island’s perimeter dyke, into the surrounding sea; when demand exceeds supply, seawater is allowed to flow back in, driving a generator. The energy island would essentially consist of a ring dyke, sealed with bentonite and enclosing an area

approximately 10 kilometers long and 6 kilometers wide. To prevent groundwater entering the enclosed lake by percolating through the substrata, the energy island would be sited at a location where there is a layer of clay tens of meters thick beneath the seabed. The water level in the 'inner lake' would be between 32 and 40 meters below that of the surrounding North Sea. It is envisaged that the lake would have a surface area of about 40 km^2 and a storage capacity of more than 20 GWh, sufficient to supply an average of 1,500 MW to the onshore power grid for at least twelve hours. Calculations have also been performed for a larger variant with 50 per cent greater capacity.

The first step was to determine the technically optimal storage system size from a power supply viewpoint. Next, on the basis of a number of scenarios for the period 2015 to 2020, the storage capacity likely to generate the greatest cost savings and the associated reduction in CO_2 emissions were calculated.
The overall time required for the construction is estimated at six years.

Cost item (billions of euros)	PAC 1 (1,500 MW / 20 GWh)	PAC 2 (2,250 MW / 30 GWh)
Dredging	0.65	0.80
Creation of building excavation and bentonite walls	0.15	0.20
Civil engineering subtotal	0.80	1.00
Housing pump generators and inlet channels	0.90	1.30
Pump generators, including mechanical and electrical components	0.50	0.85
HV cable + grid connection	0.25	0.25
Electrical engineering subtotal	1.65	2.40
Total	2.45	3.40

Table 1. Capital cost of energy island realization, in billions of euros

From the feasibility study, it is clear that a large-scale storage facility in the form of an energy island is technical realizable. Key factors in this regard are the presence of a layer of clay tens of meters thick beneath the bed of the North Sea and the fact that the technical feasibility of the engineering work involved has already been demonstrated in practice. Suitable pump generators are already available. From a power supply perspective, assuming the situation forecast for 2020, the technically optimal size for such a facility is roughly 2,250 MW / 30 GWh. From an economic viewpoint, a smaller power plant of 1,500 MW / 20 GWh is more attractive.

The usage of the power by a storage facility is not only technically feasible; it is also economically viable. The annual cost saving attainable by storing power produced overnight and returning electricity to the grid by day would be significant. Assuming a storage facility life expectancy of forty years, the saving is likely to be between EUR 1.3 and EUR 1.6 billion. The Energy Island is therefore one of the three attractive large-scale electricity storage options. In a subsequent stage, a detailed location study is planned and the technical capabilities and economic and ecological values of the other functions will be investigated.