DOT 500 PRO – PUBLIC REPORT

DEI119003

Eindverslag over de uitvoering van de activiteiten en de resultaten ervan

Title: DOT 500kW Pilot Reverse Osmosis
Abbreviation: DOT500PRO
Project number: DEI119003
Project period: 01-08-2019 / 31-12-2021

Project locations:
DOT BV office: Raam 180, 2611WP, Delft, the Netherlands
DOT BV workshop: Schieweg 15C, 2627AN, Delft, the Netherlands
Maasvlakte II, Port of Rotterdam, the Netherlands

Consortium partners:

DOT BV (Penvoerder)	Delft Offshore Turbine B.V., Raam 180, 2611WP Delft, NL
TU Delft	Delft University of Technology, Stevinweg 1, 2628CN Delft, NL

Project funding:
"Dit project is uitgevoerd met subsidie van het Ministerie van Economische Zaken, subsidieregeling Top Sector Energie uitgevoerd door Rijksdienst voor Ondernemend Nederland"

Ministerie van Economische Zaken
TOPSECTOR ENERGIE
Empowering the new economy

0. Executive summary

1.1 Background & Goal

Many regions in the world lack sufficient fresh water resources and are dependent on desalination plants as a source for both potable water as well as irrigation water. Desalination plants are expensive to operate, most notably due to their high energy consumption which is mainly dependent on fossil fuel power plants.

To reduce the CO2 emissions related to the desalination process, the DOT Wind Powered Desalination (WPD) plant uses a wind turbine outfitted with a high-pressure seawater pump that converges wind energy directly into pressurized seawater, as illustrated in Figure 1.

The goal of this project was to develop, build and test an innovative, integrated 500kW hydraulic wind turbine, capable of producing both electricity and desalinated seawater. It was planned to test this set-up at the Maasvlakte II in Rotterdam, the Netherlands.

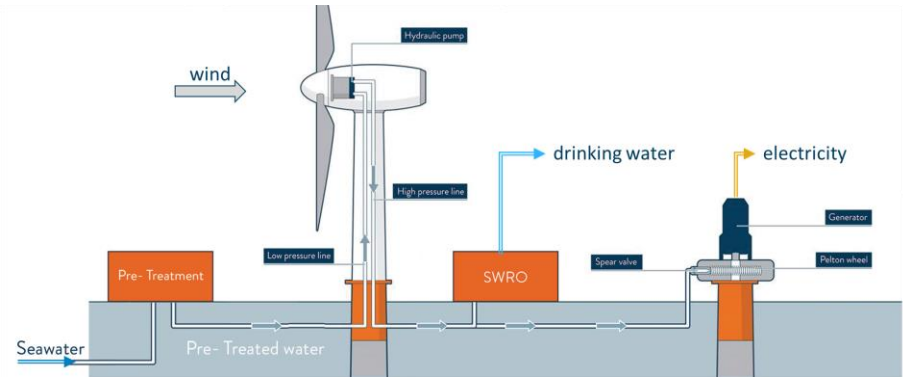


FIGURE 1 SCHEMATIC OVERVIEW OF DOT WIND POWERED DESALINATION (WPD) PLANT

A second advantage of the DOT WPD plant is that the operators are free to choose the amount of pressurized seawater to be used for electricity production, or for the desalination process, further referred to as the production of permeate. This is illustrated by the simplified hydraulic diagram of the DOT WPD plant in Figure 2.

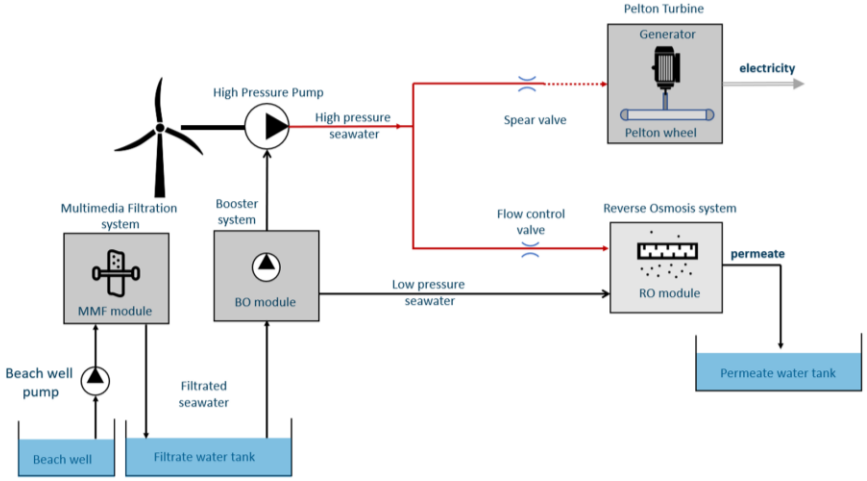


FIGURE 2 SIMPLIFIED HYDRAULIC DIAGRAM OF DOT WPD PLANT

The hydraulic energy in the seawater (red line) can be used to produce only electricity, or electricity and permeate simultaneously. The operator can choose to disable the reverse osmosis function and only produce electricity by deactivating the flow control valve.

1.2 Installation, commissioning, and testing

The installation, commissioning and testing was split up into 3 phases, located on two different locations:

- DOT Workshop, Schieweg 15C Delft
- Port of Rotterdam, Pieter van Vollenhovenweg 101, 3199 KV Maasvlakte Rotterdam

Phases 1, and partially phase 2, were performed in the DOT workshop without the use of a wind turbine. The wind turbine was simulated connecting an electric motor directly to the seawater pump and simulating the effect of the wind via dedicated software.

Phases 2 and 3 were performed on the Maasvlakte with and without the use of a wind turbine respectively. In phase 2 the wind was again simulated with the electric motor coupled to the seawater pump. In phase 3 the seawater pump was placed in the wind turbine and the wind turbine was connected electrically and hydraulically to the reversed osmoses plant.

FIGURE 3 DOT WORKSHOP TEST SETUP (PHASE 1 & 2)

FIGURE 4 MAASVLAKTE TEST SETUP (PHASE 2 & 3)

1.3 Project end results

The end result of the PRO project was a fully connected and integrated setup, located on the Maasvlakte, ready to desalinate water and to produce electricity. Inputs to the system were (a) salt water from the installed beach well, and (b) the wind as a source to power the hydraulic drive train of the wind turbine. On the output side, the setup was capable of generating electricity via the Pelton turbine, with the possibility to deliver the power back to the grid. The Sea Water Reversed Osmosis unit was ready for membrane installation, and thus to produce permeate water which can then be used in several ways.

All the activities needed to come to the above described results were followed sequentially in order to prepare for the activity Work package 6, “evaluating the performance and operationality of the plant under varying conditions”. Due to time limitations at the Maasvlakte test site, the plant could only be tested for a short amount of time, limiting the number of different conditions to be evaluated.

Throughout the duration of the project, several countries and companies were attracted to share and invest their interest in the setup. This with an eye on future possibilities and further developing projects for wind powered electricity and permeate water production, and even for possible H2 production.

1.4 Results according to project plan

A summary of the results as described in the initial project plan are as followed:

1. A Vestas V44 wind turbine was successfully customized and fitted with a hydraulic drive train directly powered by the rotor. The V44 nacelle was redesigned and reconstructed to fit a seawater hydraulic plunger pump, below the nacelle a custom hydraulic manifold was fitted to transfer the hydraulic lines from the stationary tower to the rotating nacelle. At the bottom of the turbine both high pressure lines were connected to the SWRO and Pelton turbine, the low-pressure line was connected to the water intake.
2. The Pelton turbine was revised, commissioned, and fitted on top of a 40-foot water container. The high-pressure hydraulic line was connected to the spear valve of the Pelton turbine for the production of electricity.
3. The Seawater Reverse Osmosis plant was successfully designed, engineered, assembled and commissioned throughout the different testing phases of the PRO project. The connection between either the electric motor coupled to the seawater pump or the custom Vestas V44 wind turbine fitted with the seawater pump was successfully made, connecting all the integrated systems together.

1.5 Commercial implementation and future research

The semi commercial application of the PRO project result is a next step that DOT will undertake in one of the high demand water stress, high wind energy potential regions, as described in the *“DOT 500 PRO - DEI 2019 Phase 1 - Projectplan Pilot - rev7”,* Table 5 *“potential regions for wind powered desalination”.* In the near future several spin offs, both commercial and more research and development focused, will be pursued.

1.6 Knowledge dissemination

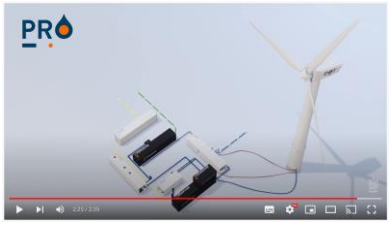
Within the PRO project multiple knowledge dissemination events and initiatives have been undertaken. The subsequent sections present the reader with an overview of these initiatives and mentions publications and media coverage that has been picked up by others outside the project consortium.

1.6.1 Delft Offshore Turbine

On the DOT website there is a short explanation of the reverse osmosis system as it has been built for the DOT 500 PRO project.

- DOT website, Reverse Osmoses: Reverse Osmosis - DOT (dotpower.nl)

On Youtube there is an in-depth movie explaining the DOT 500 PRO reverse osmosis system.



- DOT 500 PRO, Youtube, explanation movie: DOT 500 PRO v8 1 long - YouTube

1.6.2 GreenBoats

Greenboats is a German startup company specialized in the Engineering, Manufacturing and Construction of products with Natural Fibre Composite as a base material. For the DOT500PRO project they designed and manufactured the custom nacelle cover.

Uptime Wind energy dedicated a podcast, interviewing the founders and owners of Greenboats on the production and possibilities of the DOT Natural Fibre Composite Nacelle

- Uptime Wind energy, Natural Fibre Nacelle, Podcast: Can Greenboats' Sustainable Natural Fiber Composites Transform Wind Energy? - YouTube

The JEC Composites dedicated an article on the DOT Natural Fibre Composite Nacelle and the subsequential possibilities

- JEC Composites Magazine, article N° 143 – November - December 2021, JEC Group (jeccomposites.com)

1.6.3 TU Delft

Francesca Greco is a PhD student from the TUDelft within the PRO project and wrote several papers regarding the DOT500PRO project. Daniel van Hanswijk, a Master student for the TUDelft, carried out his final master thesis within the project.

- F. Greco, D. De Bruycker, A. Velez-Isaza, N. F. B. Diepeveen, and A. Jarquin-Laguna, “Preliminary design of a hydraulic wind turbine drive train for integrated electricity production and seawater desalination,” in *Journal of Physics: Conference Series*, 2020, vol. 1618, no. 3, https://doi.org/10.1088/1742-6596/1618/3/032015

- Greco, F.; Heijman, S.G.J.; Jarquin-Laguna, A. Integration of Wind Energy and Desalination Systems: A Review Study. *Processes* **2021**, *9*, 2181. https://doi.org/10.3390/pr9122181

- van Hanswijk, D., van Wingerden, J. W., & de Bruycker, D. R. (2021, September). “Learning-Based Model Predictive Control for a Wind-Powered Fresh Water Production Plant with Integrated Electricity Production (Thesis).” TU Delft. http://resolver.tudelft.nl/uuid:ffb7e6c1-25a9-4e95-8a19-3221573c04d2