

# Ruled-based control of off-grid electrolysis

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This work deals with a ruled-based control strategy to produce hydrogen from wind and wave energy in an offshore platform. These renewable energies feed a set of alkaline electrolyzers that produce H<sub>2</sub>. The proposed control system allows regulating the operation of the electrolyzers, taking into account the energy available and optimizing the performance of the plant. Simulation results obtained are presented, showing correct operation of the platform under this proposed control.

## Introduction

The aim of the H2Ocean [1]\* project was to study the technical feasibility of moving some technologies to an offshore location to reduce the demands on land resources and the associated environmental impact. The energy sources considered in this work are wave and wind energies which are attractive as non-polluting, have large reserves, wide distribution and are renewable [2]. Moreover, power produced by wind and wave energies is more reliable far from the coast, with higher power densities. Power consumption adapts to power production by connecting or disconnecting sections of the electrolyzation plant and defining the working points of the devices (following a Smart Grid approach for the microgrid in the plant) [3]. Compared with previous work [4,5], we concentrate here on a specific control system to regulate the operation of the electrolyzers, taking into account the green energy available and optimizing the performance of the platform.

## Problem statement

Fig. 1 presents the main components of the offshore electrolysis plant. Wind and waves are the energy sources of the electrolysis process that produces H<sub>2</sub>. The H<sub>2</sub> is then stored and transported onshore to the final users. As power supply changes with time, the production of H<sub>2</sub> has to adapt to the available power using the control system approach proposed in this work. Offshore power links are known to be significant expensive, so the system is here assumed to be fully isolated from the grid, following the approach presented in [6]. In this work a realistic electrolyzation installation is considered, with multiple electrolyzers that are installed in set of Electrolyzation Lines composed of a few electrolyzers that share some components (Iye circuits, deoxidisers, compressors, etc).

## Control proposal

Electrolyzers work correctly at fluctuating current (power input, denoted as Net Available Power, AP): However, electrolysis products tend to get impure if the load level (called here percentage of usage, PU) is lower than 15% of full capacity, so the target is then to maintain always the electrolyzers operating within the range of 20-100% of full capacity. Moreover, as the maximum yield is obtained when operating near 20% and the power input is variable, a control system is needed to regulate the number of electrolyzers operating near this value, but always in a safe area. In our proposal the electrolyzers are installed in lines, so we assume the installation is composed of a certain number (Num\_max\_elect) of Electrolyzation Lines (ELL), each of them absorbing a maximum power denoted PEL\_max. The control algorithm is based on the following objectives:

1. Keeping the percentage of usage (PU) identical on all ELL, and always in the interval 20-100%: if the PU is expected to be less than 20%, the number of active Electrolyzation Lines (ELLa) will be decreased.
2. Keeping the PU < 90%: if the PU is expected to be more than 90% then ELLa is increased, if possible.

The amount of H<sub>2</sub> that is produced is calculated with an ideal capacity factor of 100%. The capacity factor is named as the ratio of its output over a period of time. The control algorithm is based on the following basic rules, where NA

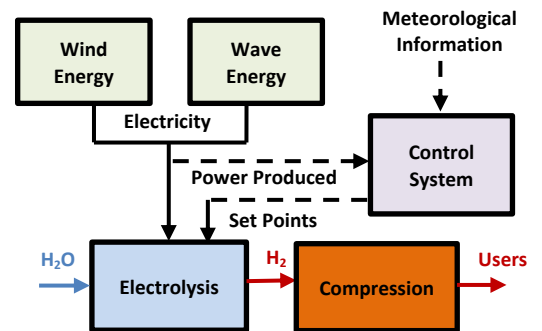


Figure 1. General scheme of the electrolysis plant.

(respectively, NE) are the number of electrolyzer lines to disconnect (resp., connect) at each sample time:

IF  $(AP(k) / ELLa(k) < 0.2 PEL\_max)$  AND  $(ELLa(k) > NA)$  THEN  $ELLa(k+1) = MAX(ELLa(k) - NA, 0)$   
 IF  $(AP(k) / ELLa(k) < 0.2 PEL\_max)$  AND  $(ELLa(k) \leq NA)$  THEN  $ELLa(k+1) = ELLa(k) - 1$   
 IF  $(AP(k) / ELLa(k) > 0.9 PEL\_max)$  AND  $(ELLa(k) > NE)$  THEN  $ELLa(k+1) = MIN(ELLa(k) + NE, Num\_max\_elect)$   
 IF  $(AP(k) / ELLa(k) > 0.9 PEL\_max)$  AND  $(ELLa(k) \leq NE)$  THEN  $ELLa(k+1) = ELLa(k) + 1$

### Application to a case study

To validate the proposed control system, a platform with 67 vertical axes wind turbines (VAWTs) of peak power 5 MW, 95 wave energy converters (WECs) of peak power 1.6 MW, and 150 electrolyzers of peak power 2.4MW was considered. An initial image of the hybrid VAWT-WEC concept is shown in Fig. 2. To produce H<sub>2</sub>, 150 NEL A485 electrolyzer units (NEL-Hydrogen, 2014) are grouped into 10 Electrolyzation Lines. Thus, the following parameters were used to carry out the simulation: Num\_max\_elect = 150, PEL\_max = 2.4 MW. In the first simulations it was selected NA = 3 and NE = 2 because it was empirically shown that with these values the performance was adequate. Some partial results for 500 hours of operation are shown in Fig. 3 to 5: Fig. 3 shows the power provided by the renewable energy sources. Fig. 4 shows the percentage of usage during this period of time and Fig. 5 depicts the number of electrolyzers in operation. Fig. 6 shows the percentage of usage during this period of time. The amount of H<sub>2</sub> produced is 91350 Nm<sup>3</sup>/h

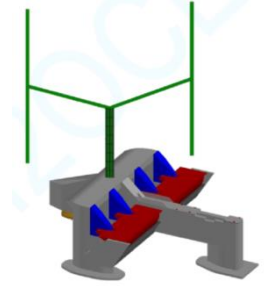


Figure 2. Hybrid WEC-VAWT device.

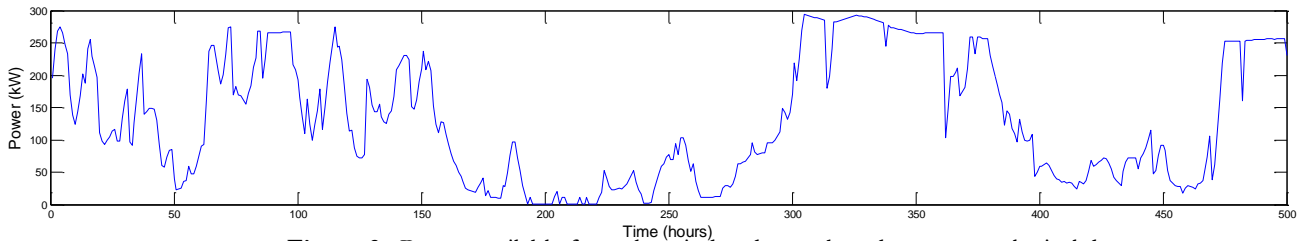


Figure 3. Power available from the wind and wave based on meteorological data.

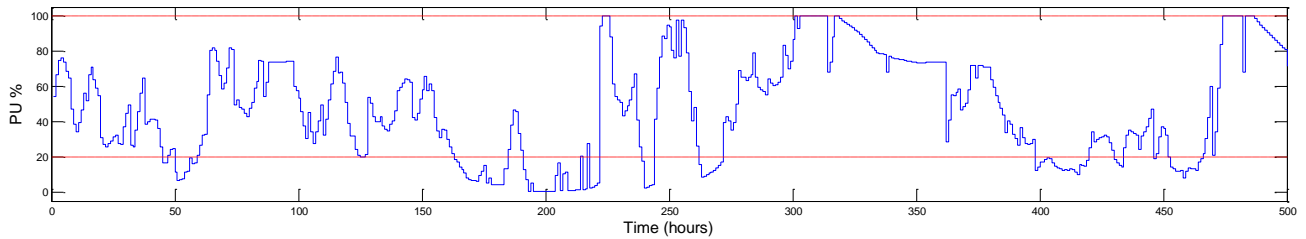


Figure 4. Percentage of Usage.

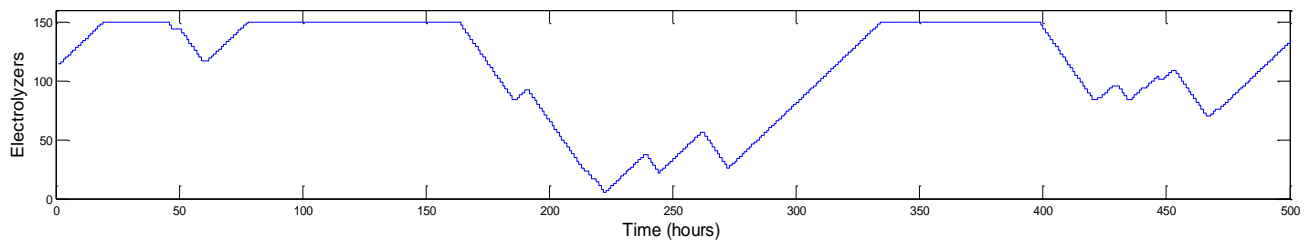


Figure 5. Number of electrolyzers (each produces 609Nm<sup>3</sup>H<sub>2</sub>/h).

### References

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