D7.4 Report on possible integration of developed PEM electrolysis technology with renewable energy sources

Statoil

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Author(s)/Source(s):
Stein Trygve Briskeby
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TPD RD NEH ESY	**Stein Trygve Briskeby**	**13.08.2012**
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TDP RD NEH ESY	**Per Øyvind Hjerpaasen**	**30.10.2012**
Recommended (Organisation unit):	Recommended (Name):	Date/Signature:
TDP RD NEH ESY	**Oddmund Wallevik**	**18.10.2012**
Approved by (Organisation unit):	Approved by (Name):	Date/Signature:
TDP RD NEH ESY	**Per Øyvind Hjerpaasen**	**30.10.2012**

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1 Objective

This report gives an overview of the Energy Park at Statoil Research Centre in Porsgrunn, and plans for the testing of one of the electrolyser stacks developed in the NEXPEL project. This work is part of WP 7 in EU Project NEXPEL, “INTEGRATION AND FIELD TESTING WITH RES”, and is dedicated to field testing of the NEXPEL electrolyser stack. In order to achieve efficient operation a new DC/DC converter is being designed and constructed especially for this electrolyser by Fraunhofer ISE. The DC/DC converter will be installed in Porgrunn, and used for running the electrolyser on variable load. The field test is planned to take place from October – December 2012.

In case unforeseen problems related to stack manufacture or DC/DC converter operation, fall back options involving installed equipment in the Energy Park are proposed.

2 The Energy Park

Statoils Energy Park at Herøya, Porsgrunn, Norway, is a test centre for renewable energy and energy storage. It consists of two 6 kW wind turbines (Proven Energy) (Se Fig 1) and two 2.1kW monocrystalline Si based solar panels (Solartek, GPV). The wind turbines are Down-wind self-regulating turbines with a rotor diameter of 5.6 m. It is a gear-less turbine with permanent magnet direct drive generator. The park is equipped with a 70 kWh lead acid battery storage system, and can operate as a standalone unit or be connected to the main grid for export. The facility can be used for testing the combination of renewable power sources with water electrolysis. Other applications include testing of control systems for wind power production as well as testing of components for energy conversion and energy storage systems. The park is located by the hydrogen filling station at Herøya

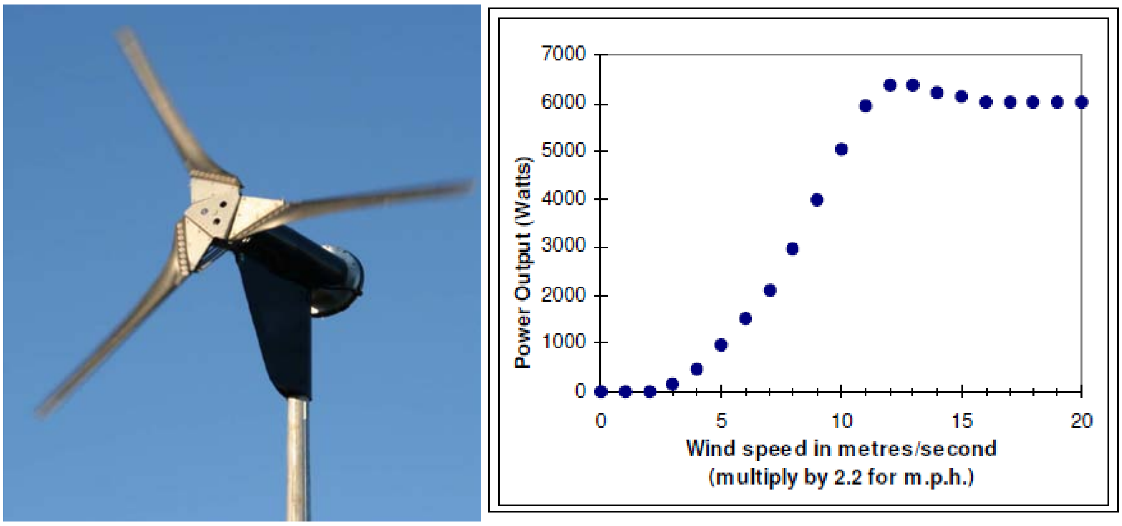


Fig. 1: Proven WT6000 and power curve.

A picture of the Energy Park is shown below.

Fig. 2: The Energy Park and the Hydrogen refueling station at RCP in Porgrunn. Note that as of May 8. 2012 the hydrogen refueling infrastructure is taken over by a new company called HYOP, and is no longer part of Statoil activities.

A single line diagram of the layout for the energy park is given in Fig. 3. The DC/DC converter will be connected to the DC bus (48- 56 VDC)

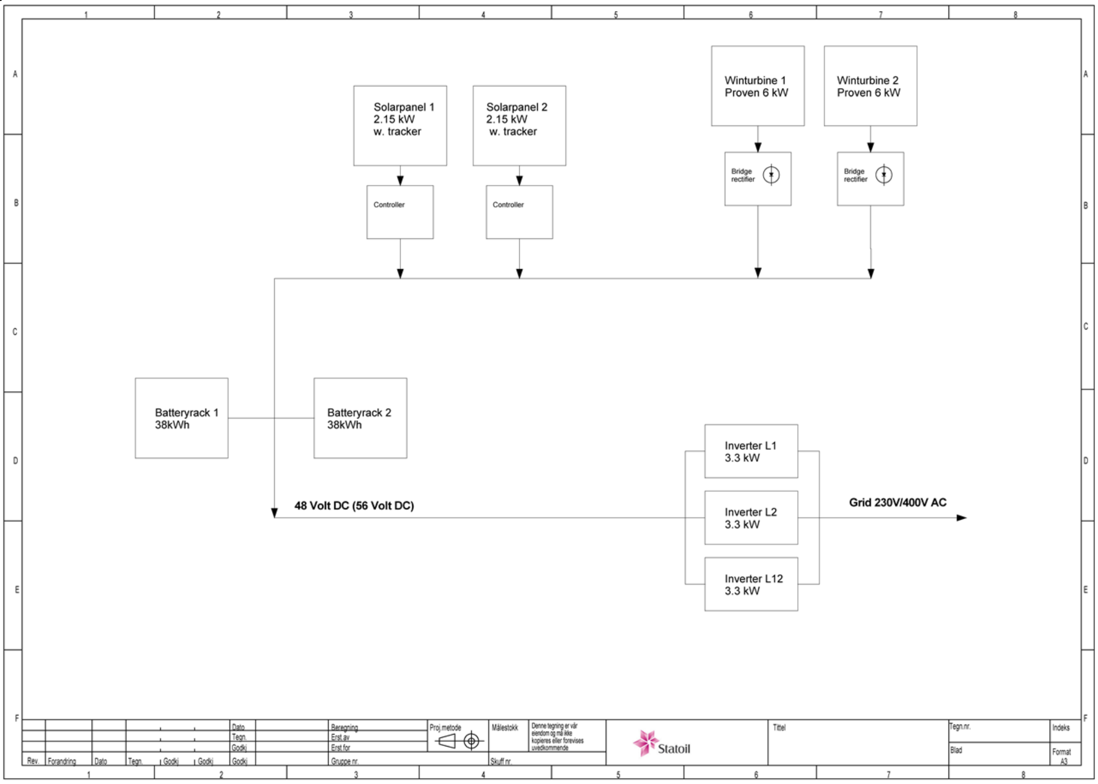
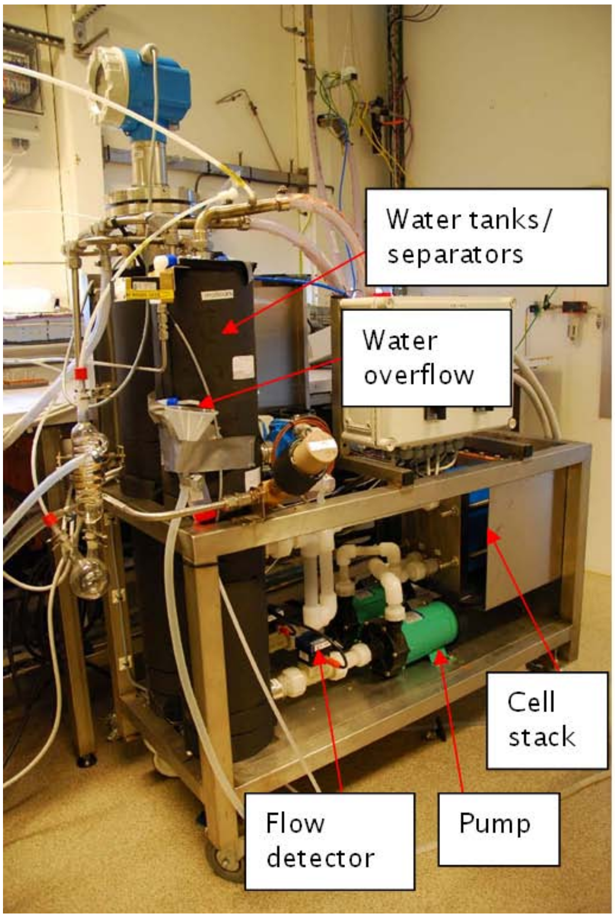


Fig. 3 Single line diagram of the Energy Park

3 Laboratory facilites

Integration of the stack in the energy park will take place from M30. However, work has already been done to prepare the laboratory for the test. The electrolyser skid (See Fig. 4) intended for testing with the stack is not instrumented with EX equipment, hence a custom made fume hood (Fig. 5) has been built around the equipment. A fan with a ventilation capacity of 2480 m^3/h has been installed (DVEX 355D4 Roof Fan, Atex. Calculated ventilation need >1800 m^3/h). The ventilator is set to maintain an under pressure during operation. If a hydrogen leakage is detected, either as H2 in O2 in the O2 separator, or inside the fume hood, the fan is stepped up to its maximum capacity, and the electrolyser is shut down.



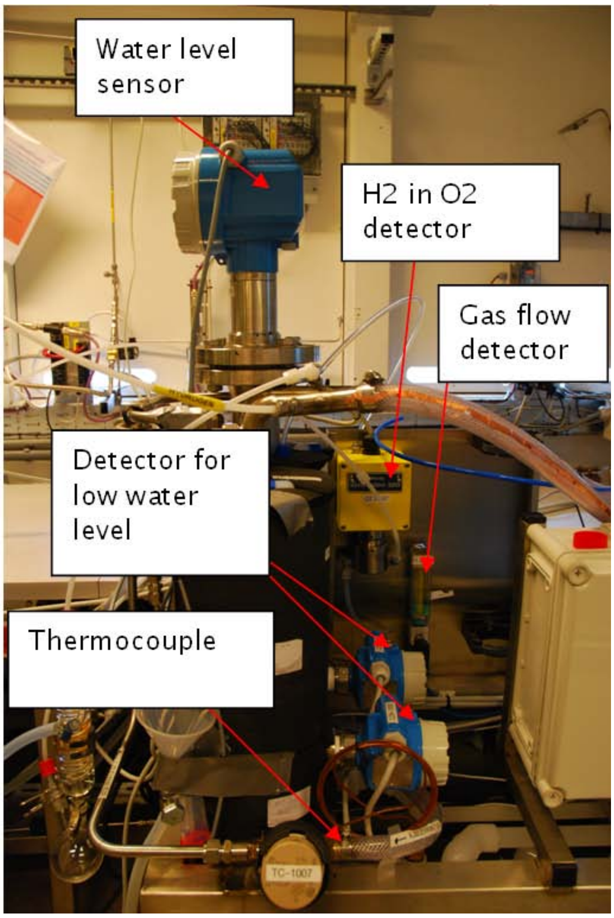


Fig. 4: Electrolyser skid

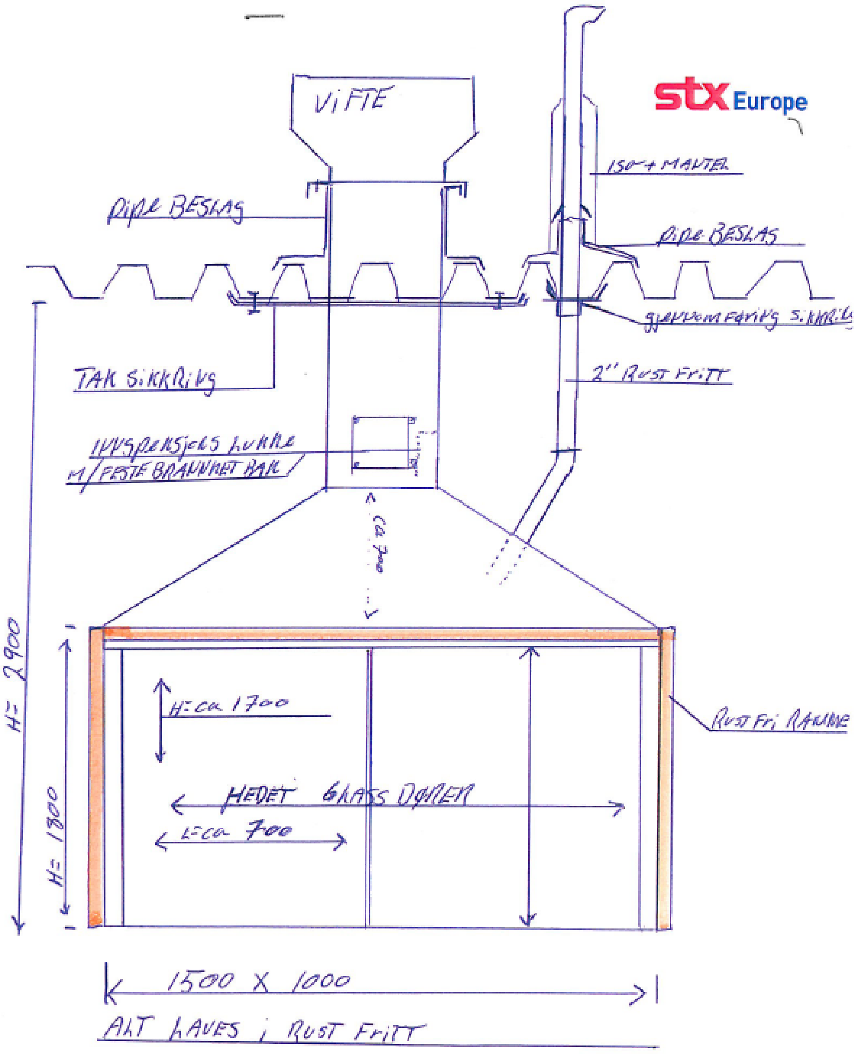


Fig. 5:Custom made fume hood located in the garage

Purified MilliQ water is supplied from an Elix-Advantage 15 water purification unit upgraded with a “Clinical Upgrade Kit” and “E-Gard Upgrade Kit”. Water and sewer pipe was not installed in the garage, and a ditch had to be made from the garage to a nearby drain. (Fig. 6)

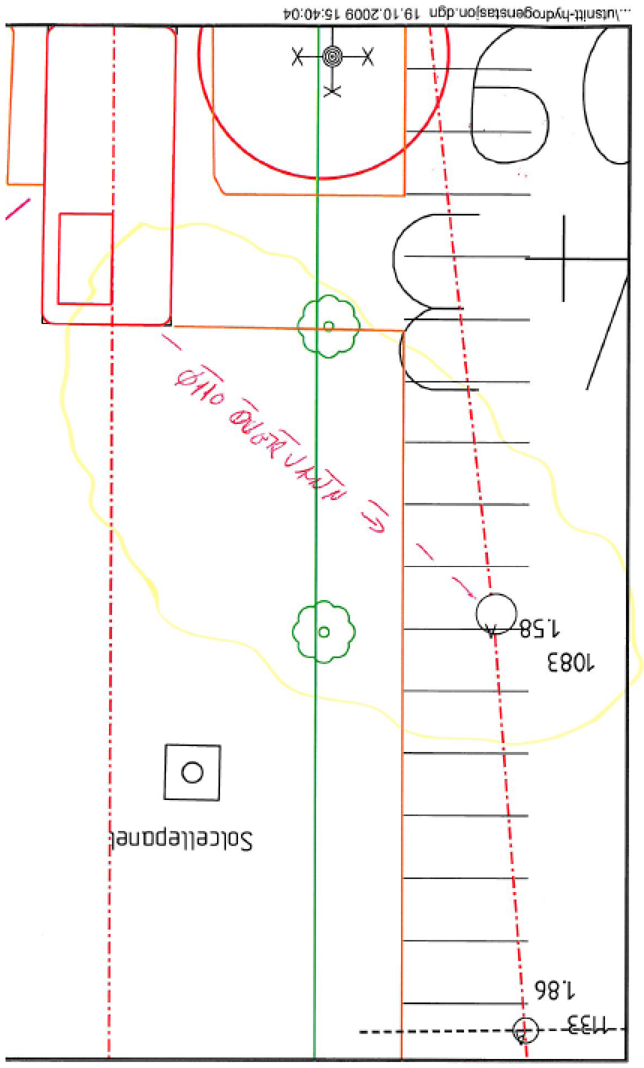


Fig. 6: Locataion of drain ditch

The electrolyser is controlled from a LabView interface giving input to the PLC. A screen dump from the LabView interface is shown in Fig. 7. Data is logged on a second basis and stored in citadel database. The PLC sequences run continuously, and will initiate controlled shutdowon should any of the events given i Table 1 occur.

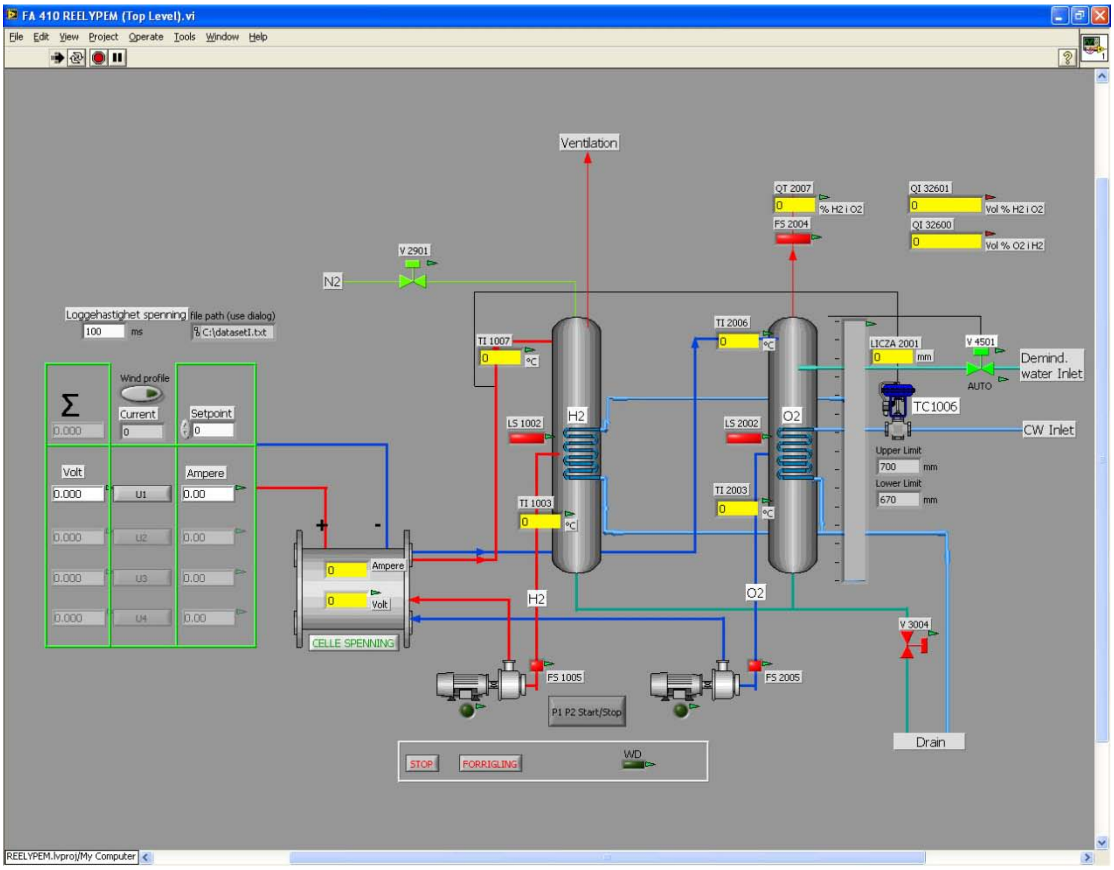


Fig. 7: Screen dump from LabView interface

Tab. 1. Events leading to controlled shutdown

Tag nr	Description	Value
TZH 1007	H2 temp from stack	90C
TZH 2006	O2 temp from stack	90C
LZL 1002	Low water level H2 separator	50%
LZL 2002	Low water level O2 separator	50%
LZL 2001	Low water level O2 separator	46%
FZL 1005	Low water circulation H2 side	10l/min
FZL 2005	Low water circulation O2 side	17 l/min
FZ 2004	Low flow to gas analyzer	10%
QZH 2007	H2 in O2	0.4 %
QZHH 2007	H2 in O2	1.0%
QZHH 3002	H2 in fume hood	40 % LEL
PZL3001	Under pressure in fume hood	0.05 mBar
HZ3003	Emergency stop	On/Off

If the emergency button is pushed, all power to the system (including rectifiers) is cut and ventilation is set to maximum for 30 minutes. The gas quality may, in some operational circumstances, reach 0.4 % H_2 in O_2 for short periods of time, e.g sharp changes in load, hence a delay of one minute is implemented if QZH 2007 is triggered. All other events trigger the ventilation and cuts power supply to the control cabinet. The rectifiers are set to zero, and are shut off completely after 5 minutes. This feature is implemented to prevent damage to the rectifiers.

Pictures from the laboratory are shown in Fig**.** 8

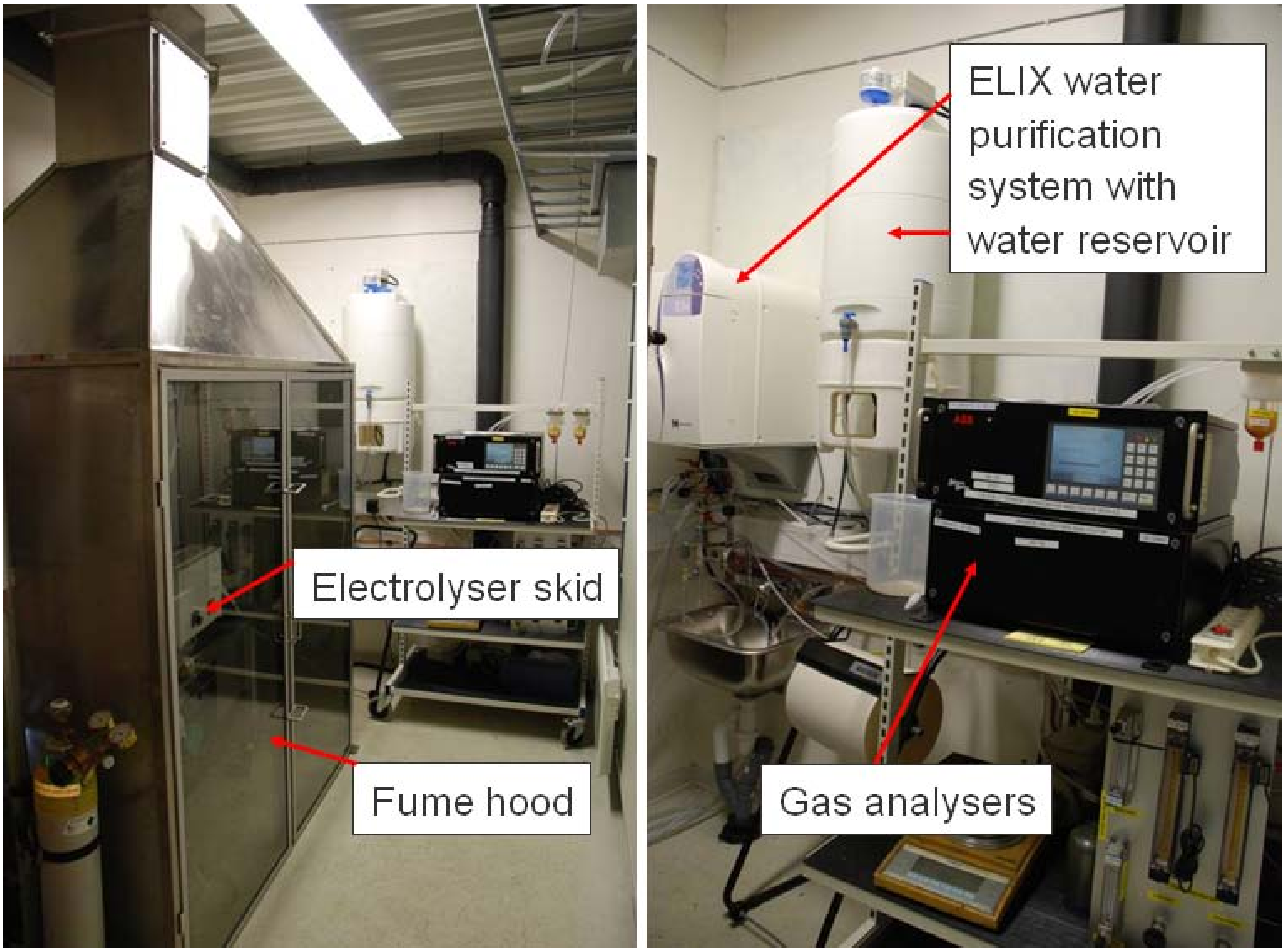


Fig. 8:. Pictures from the laboratory in the Energy Park

4 Electrolyser testing

The electrolyser testing consists of 6 different types of studies:

1. Conditioning
2. Water Quality
3. Gas Purity Study
4. Pressure Study
5. Temperature Study
6. Durability Study.

Not all of these are applicable at all test sites. Statoil will not perform Pressure and Temperature studies, as the stack will be operated at atmospheric and "autothermal" conditions only.

The following terminology has been agreed upon by the consortium in the formulation of testing procedures:

- Umax : Maximal cell voltage. Umax = 2.1 V to prevent titanium oxidation.
- Imax : Maximal current density corresponding to Umax.
- KH100 : Hydrogen ratio into oxygen.
- KH100max =1.5 %

4.1 Conditioning

Fumatech advises to condition its MEA at a cell voltage below 1.9 V, 60 °C for 100 h. Polarisation curve every 20 h from OCV to 1.9V.

Based on these requirements, the conditioning will last 100 h then a reference polarization curve will be made from Imax (Umax) to 0 A/cm². The stack installed in the Energy Park will operate at atmospheric conditions in "autothermal" mode (No temperature control other than cooling if maximum temperature is exceeded)

4.2 Water quality

In order to maximize stack durability, water conductivity will be monitored over the total period of test. As a recommendation, it will be necessary to purge the anode water loop and refill it with DI water each time the conductivity level goes above 0.5 µS/cm.

Based on experience from running REELYPEM at Statoil continuous bleed and water refill has been found necessary to maintain high quality of the water. The electrolyser has a u-tube connecting the oxygen and hydrogen separators. Continuous bleed and refill corresponding to 7 times water consumption has been used up to now. The u-tube may be plugged if the project finds it necessary. In this case water will be drained from the cathode separator and refill of water will be done in the anode separator. Measuring water quality is a manual operation, online measurements is not possible.

In addition to this monitoring, different water samples will be taken from the separators for further water analysis at different period of time. ICP measurements will be done to trace metal ions possibly released by some components of the stack.

Time interval for sampling of water:

- Once every day (24h) during conditioning
- During durability study, every 96h (once each cycle, during the constant load operation).

Random samples will be circulated for round robin tests. Looking for: Conductivity, (pH), Fluorine/fluoride, Titanium, Iron, Nickel, Iridium, Platinum, Chromium, (Antimony), (Tin), Silicon. (Elements in brackets are for the stack with Ir/ATO).

4.3 Gas purity study

The objective is to characterize each stack in their reference condition for different constant loads at 1 A/cm², 0.5 A/cm² and 0.2 A/cm² until stable values are achieved. Cell voltage and KH100 evolution will be recorded over time. The evolution of cell voltage and gas purity against current density will be drawn.

4.4 Durability study

Once the characterization tests are finished, the stack will be operated on long term tests. The objective is to exceed 1000 h of testing. First the stack will be operated 200 h minimum at constant current density, for example at 1 A/cm².

The durability study will be based on a 72h wind profile supplied by Statoil. The wind profile is given in Fig. 9. The wind profile will be scaled according to the capacity of the stack, and have a cut-off at low power to avoid poor gas quality. For the first wind profile test cycle, the wind data will be average on minute basis. The second cycle will be averaged on 10 second basis. The following cycles will be run on 1 s resolution if possible. Details are given in Tab. 2.

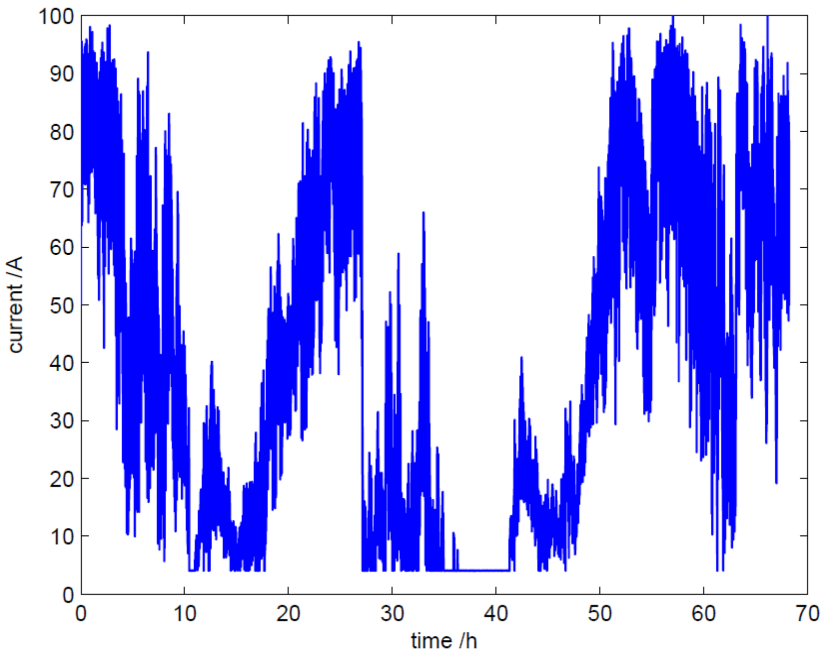


Fig. 9: Statoil Wind profile

Tab. 2: Durability test.

Cycle			
1	72h wind profile	1 minute resolution Average of 60 points	24 h constant 1A cm-2 + polarisation curve (from Umax to 0)
2	72h wind profile	10 second resolution Average of 10 points	24 h constant + polarisation curve (from Umax to 0)
3	72h wind profile	1 second resolution (if possible)	24 h constant + polarisation curve (from Umax to 0)
4	72h + 72 h wind profile	1 second resolution (if possible)	24 h constant + polarisation curve (from Umax to 0)
n	72h + 72h wind profile	1 second resolution (if possible)	24 h constant + polarisation curve (from Umax to 0)

The same profiles will be repeated over time until the cell voltage goes beyond Umax or gas purity beyond KH100max. Regularly, between each cycle, an IV curve will be performed to detect cell voltage degradation and a stable current density will be imposed to have a view on gas purity.

5 Fallback options

5.1 REELYPEM

Currently, the electrolyser skid is equipped with a PEM electrolysis stack developed by Statoil in cooperation with NEL Hydrogen (Formerly known as Hydrogen Techologies before being sold out of Statoil.) This stack has been tested on variable load in a cooperation with IFE (Institute of Energy Technology). It is suggested to keep this stack as a fallback option in case the fabrication of the NEXPEL stack for the energy park fails. In this case, the developed DC/DC converter may still be tested on a variable load supplying power to an electrolyser. The specifications for the stack are given in Table 3. As seen from the table, this stack has a higher voltage input than the planned NEXPEL stack. In order to meet the required input for the stack and at the same time being able to use the DC/DC converter, it is possible to connect one or more of the Xantrex power supplies in series with the DC/DC converter and set the Xantrex supplies to operate at constant voltage (Fig. 10). In this operation mode, the DC/DC converter will supply the required voltage on top of a constant voltage and thereby control the current supplied to the stack. In this way the DC/DC converter can be tested within its operating window.

Tab. 3: REELYPEM specs.

Number of cells	25
Cell area	100 cm^2
Current range	6-100 (110) A
Capacity	1 (1.2) $Nm^3 h^{-1}$
Stack voltage	36-52 V
Gas purity	< 0.2 % H2 in O2

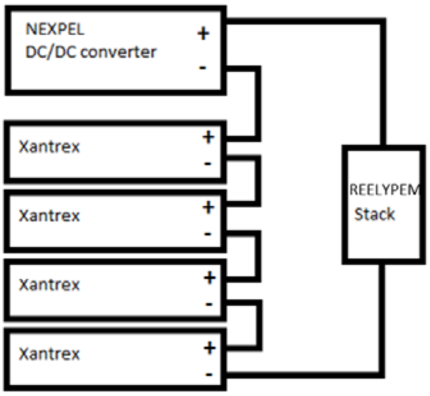


Fig. 10: Possible layout for testing NEXPEL DC/DC converter with REELYPEM stack

5.2 Failure of DC/DC converter

4 Xantrex rectifiers coupled in series are installed in the laboratory, and can be used as backup power supply for the electrolyser in case of malfunctioning of the NEXPEL DC/DC converter. This way results for the NEXPEL stack can still be obtained.