Institute for Sustainable Process Technology

Advanced Process Control HydroHub

APC / SI-50-11

Partners

Hanzehogeschool Groningen University of Applied Sciences

Institute for Sustainable Process Technology

TKI ENERGIE EN INDUSTRIE Topsector Energie

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Project partners: ISPT, TNO, Hanzehogeschool Groningen (EnTranCe), Yokogawa

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Researchers (name & title thesis)	-
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1.0 Public summary

General

The ISPT Hydrohub Innovation program consists of different projects such as Hydrohub MegaWatt Test Centre (HHMWTC) project running under TKI support.

The HHMWTC, an experimental facility, is being developed for experimentation with full-scale small industrial PEM and Alkaline units of 250 kW each. These facilities are under construction at Energy Research Center EnTranCe (www.entrance.org) of Hanzehogeschool at the Zernike campus. The initial goal of the current project phase is aimed at running a series of studies to test basic operations, identify the window-of-operation and explore limitations in stress-tests to understand the optimal operation window and limitations of equipment. Another aim is to develop an open-innovation ecosystem in which the MW test centre supports further advanced technology development for electrolysis.

The APC project is the first addition to the original project of the development of HHMWTC which extends with this correlated project on advanced process control.

Production of hydrogen from renewable power sources requires dynamic operation of electrolysers. A dedicated research project has been executed in which models have been created trying to determine the impact of variable operation on electrolyser performance and the electricity grid. In addition optimal control strategies will be developed by verifying the model results in reality on the PEM electrolyser with the goal to improve overall operational efficiency. Advanced Process Control has been implemented in other industries successfully to improve efficiency and optimize multiple parameters simultaneously by considering the interaction, process dynamics and buffering and release of mass and energy in reactions. In this case of the flexible production of the green hydrogen, this is a totally new way of process control for electrolysers.

It is expected that by applying advanced control strategies 2 to 3 % operational efficiency gain can be achieved. The research proposed in this project is aimed to research, model, and test this potential efficiency gain on the PEM unit.

Context

Hydrogen from renewable power sources has a key role in energy transition reducing CO2 emissions related to industrial activity, contributing as sustainable industry feedstock as well as energy carrier. Production and scale-up of hydrogen from renewable sources is a key challenge of the multi-annual mission-driven innovation program on electrification (MMIP8). Because this production route is driven by wind and solar, understanding how to optimize dynamic and flexible operation is key factor contributing to this mission.

Materials and construction of electrolyser systems are sensitive to damage from e.g. high temperature while safety issues may arise at low flow. This means certain temperature, pressure and flow thresholds may never be exceeded. On the other hand, optimal efficient production often is at values close to these threshold values.

In a fixed operation setting, material flow and cooling etc. can be tightly tuned to well-known operation conditions and not many disturbances have to be squared away.

Another challenge is the impact on the power quality in the feeding electrical power grid: Power electronics to transform and rectify the AC feed to DC create disturbances on the power grid (wave form, phase shift etc.). Grid operators will charge higher prices, impose fines or won't allow connection altogether if these disturbances are too high. Rectifiers can be optimized for operation in a narrow bandwidth but may require tuning when used in different envelopes.

Current research on materials and system construction will make future electrolysers more resilient and widen the operating envelope. Nonetheless future systems will still have a trade-off between wear and efficiency. In this project dynamic behaviour and control optimization of dynamic parameters will be studied, modelled, and tested to create a more stable overall system that mitigates fluctuating demand and supply.

Current electrolyser 'Balance of Plant' control uses single loop feedback control to regulate the important parameters separately. A value is measured, and if exceeded an adjustment is made to correct the balance. The interaction of parameters is mitigated by tuning one loop stronger than the other, so the more important parameters are responding best to variations. All these corrections are reactive and based on measured deviations; There is no pro-active action to process variations. This can be illustrated with an example. Advanced control, rather than waiting for the temperature at the outlet to increase, will anticipate an increase of heat generated in the electrolyser stack when the power increases. Taking into account buffering of mass and energy in the system, advanced control will take action to prevent the potentially harmful temperature increase.

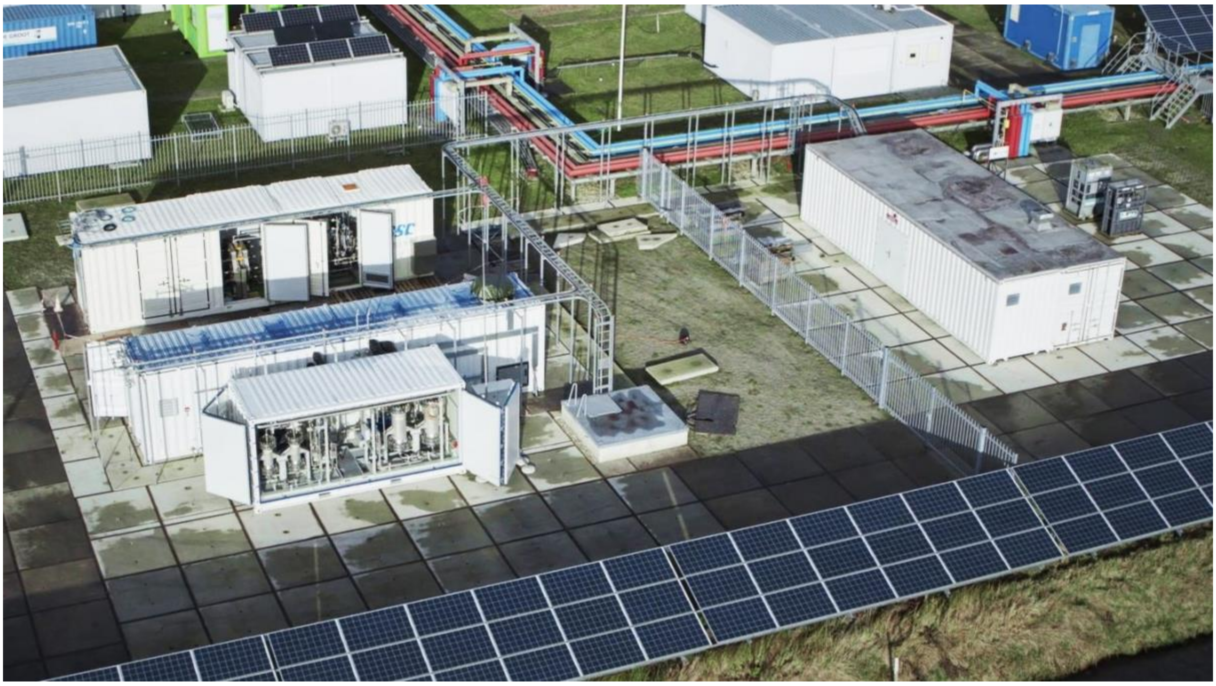
A second goal is to understand if an advanced control system could assess to what extent degradation has occurred in the electrolyser stack. It is challenging to measure parameters within a running electrolyser. However, measured (external) process variables like current, voltage drop, pressures and temperatures, yield etc can possibly be used to assess the state-of-health. Models will be developed to provide insights in the possible tell-tale patterns and there effects. This will be the input for actual tests at the MegaWatt Test Centre with the advanced control system of the electrolysers. This is an iterative process where the actual results will be fed into the models which will provide new test setting. The end goal of the process is to help improve overall electrolyser operation/efficiency.

Project goal

The goal of this project is to implement Advanced Process Control (multi-variable, model based control) on overall electrolyser systems to optimize production while staying within material and safety thresholds and to investigate the options of advanced process control of electrolysers and determine whether parameters can be found by applying advanced control mechanism to support improved efficiency of electrolysers in the future.

The PEM unit of the Hydrohub system will be used to test implementation and validate results.

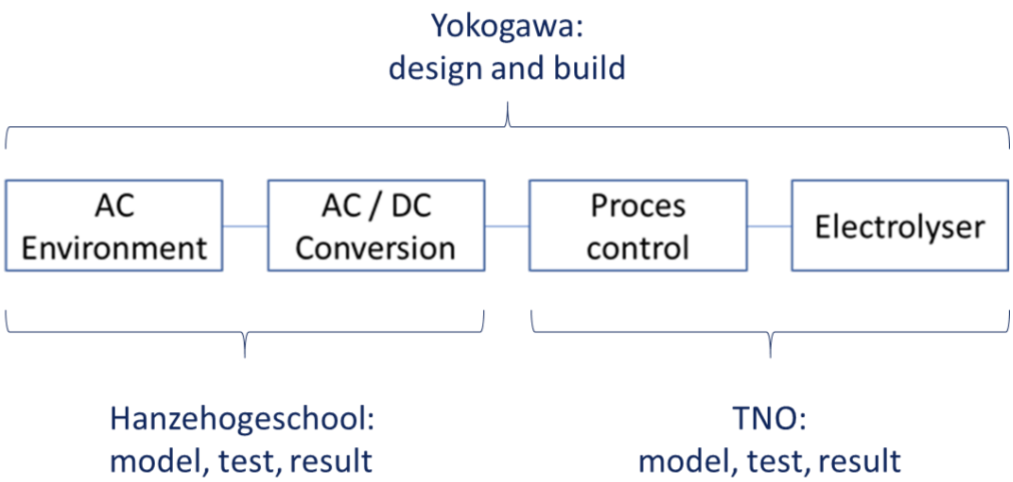
In other areas of industry, sensitive equipment is often dynamically operated at optimum level, close to the critical envelope. This is supported by feedback control, but also by more advanced control like e.g. feed-forward, model based or multi-variable control. The project goal is to make a new type of control schemes from other areas of industry to relevant parameters and models for electrolysers and make electrolysers more flexible and faster responding in production rate, driven by power availability and pricing.



Picture: Hydrohub MegaWatt Test Centre (HHMWTC) at “EnTranCe” in Groningen.

Results

The project achieved to prepare the required models. The first model provides insights in the Power Quality (harmonics) of the local power grid in combination with electrolyser operations. The second model provides insights in electrolyser operations especially the temperature in the stack at various loads. The advanced process control has been designed and build.



A base measurement of the Power Quality has been performed and the project is waiting on the completion of the HHMWTC, especially the PEM unit to execute the field test and verify the model results with the actual results. This would be the basis to determine whether the 2 -3% improvement is feasible and how electrolyser operations influence the local networks.

The HHMWTC project encountered several design challenges and setbacks in deliveries and availability of resources. The worldwide COVID-19 pandemic has enlarged the challenges and set-backs leading to significant delays in the works. The delays and issues to overcome have prevented the actual tests to take place.

Although the APC project has been ended the test work will be executed once the HHMWTC is fully commissioned. The HHMWTC is being commissioned and the test work and results of the APC project are expected mid-2024.