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QUALIFYING TESTS AND ECONOMIC ANALYSIS OF ELECTROLYZERS FOR GRID SERVICES

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As part of the European project QualyGridS, drafts for standardized testing protocols for electrolyzers to perform electricity grid services are defined and elaborated. These protocols are designed to be used by alkaline and proton exchange membrane (PEM) electrolyzers up to the Megawatt scale. The protocols are being submitted for standardisation. Testing results using these protocols on a state-of-the-art PEM electrolyzer system of 50 kW with 1500 cm^2 area stack are presented with considerations of the influence of balance of plant (BOP) components. System behaviour of 50 kW and Megawatt PEM electrolyzers are compared to determine the influence of their scale in performance and response time. An economic analysis has been conducted in the scope of the project. Today's situation has been analyzed in a first part: the objective was to identify the best way to combine H_2 supply for a primary value stream and provision of grid services. A second part of the analysis studied the potential future evolutions that could change the current picture.

Keywords: PEM electrolyser, grid service, dynamics

INTRODUCTION

The potential of water electrolyzers (WE) to provide different services to the grid has been widely discussed in the literature [1-3] as well as initially demonstrated in pilot projects in the EU [e.g. 4]. The electrolysers are capable to generate hydrogen for different applications, as flexible loads are connected and disconnected when demanded by electricity distributors (Transmission System Operators (TSO), Distribution System Operators (DSO) and peer-to-peer operators) and gas grid operators. Thus, flexibility is defined as the modification of injection (through generation) to the grid and/or withdrawal (through consumption patterns) from the grid, in reaction to an external signal in order to provide a service within the energy system [5]. For electric grids, it implies covering certain parameters like amount of power modulation, duration, rate of change or response time. Flexibility is going to be increasingly needed in the EU due to widespread introduction of renewable energy sources (RES) in the electric grid in such a way that non-dispatchable generation will replace the traditional generation. In this context, the benefits from flexibility in the demand side may lead to key achievements such as: (i) being able to increase the amount of RES in the system, (ii) avoiding or delaying network reinforcement; (iii) systems operators being able to successfully match generation and demand.

Some of the gaps for further market penetration of electrolyzers operating on renewable electricity are the precise analysis of performance requirements, definition of standardized tests for qualification of electrolysers and development of business models combining various electrolyzer uses. These issues are addressed throughout the QualyGridS project [6].

SCIENTIFIC APPROACH

Based on existing electricity grid services in the European countries with the published prequalification procedures and typical operation patterns testing protocols for electrolysers were worked out. The grid services are grouped based on the recommendations of ENTSO-E, however there are still differences between the countries. Recently some changes of the services were seen based on the EU Commission Regulation 2017/1485 [8] giving guidelines for transmission system operation.

Testing protocols from our project QualyGridS try to unify the variations in the grid services throughout Europe to make sure that an electrolyzer passing these tests will be capable of doing grid services in all countries that offer this service. With specific tests for given grid services as well as basic characterizations identifying the most relevant capabilities for this application parameters like dynamics and stability are tested.

An example of such a unified testing protocol for FCR (Frequency control reserve) is given in Figure 1. FCR requires the fastest power variations of the different services available in many countries and can achieve interesting remuneration rates.

The testing protocols were applied to a 50 kW electrolyzer operated at DLR (Fig. 2). This PEM electrolyzer manufactured by Hydrogenics uses a 6-cell 1500 cm^2 area stack and can be run up to 2 A/cm^2. Stack and system concept are built in an equivalent way as for the 1.5 MW PEM electrolyzer operated at Uniper in Reitbrook, Hamburg. However, the 50 kW electrolyzer can be considered rather as a test bench for the large area short stack and it is by no way an optimized system for an electrolyzer with 7.5 Nm^3/h hydrogen production.

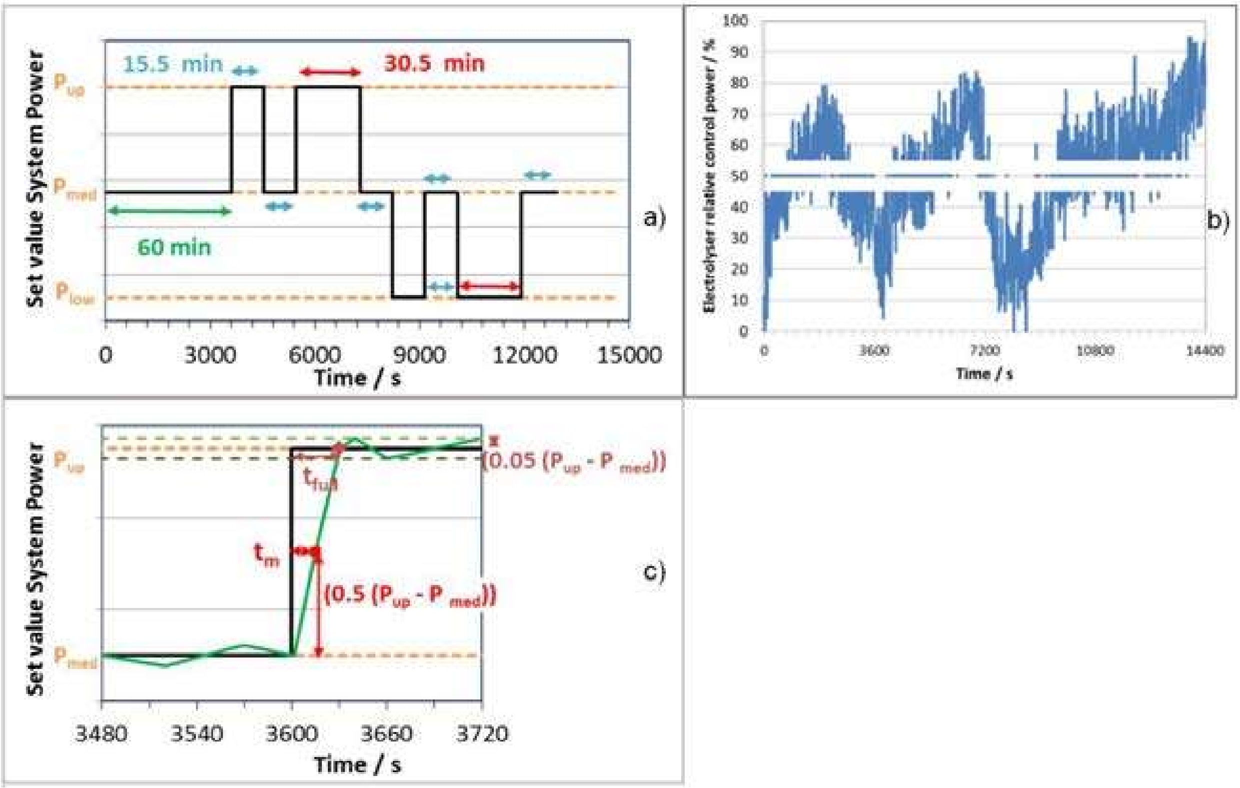

Fig. 1: QualyGridS suggested unified FCR testing protocols and evaluation. a) Testing protocol part 1 derived from prequalification procedures; b) Testing protocol part 2 derived from a real case of grid frequency input; c) Evaluation of activation times and stability. Pass criteria: t_m. ≤ 15 sec, t_{full} ≤ 30 sec, stability ≤ 0.05 (P_{up}-P_{med})).

Fig. 2: process room (left) with stack and operation room (right) with HMI (Human machine Interface) and DI water processing of 50 kW experimental electrolyser used at DLR

RESULTS AND DISCUSSION

The reaction of the stack power to the step power change request will be given in the presentation. While the stack behaviour is comparable at all scales and highly dynamic the system architecture, control strategies, volumes and dynamics of components have a strong influence on the ramping rates and the stability of the total power consumption. In comparison a startup ramp from hot standby of the 1.5 MW electrolyzer is shown. FCR requests a maximum duration of the ramp of 30 seconds. This is achieved by the full size electrolyzer but not by the experimental smaller electrolyzer. The reason for the slower behaviour of the smaller system is the setup of the BOP components: pressure control is slower, ramp speed of the rectifier is limited and the safety conditions for the system prevent it from faster changes. However the 1.5 MW system is not designed for very fast changes of power. Hydrogenics has with the same stack technology also set up a 2.5 MW electrolyzer in Markham, Canada, that follows the grid's power request within seconds [7].

Similarly alkaline electrolyzer systems are tested in the project and it could be shown that with the right systems setup they can just as well achieve the necessary dynamics and stability to perform grid services.

The economic analysis of electrolyzers performing grid services was set up in several stages: in a first stage 2017 economic data of grid services in Europe were collected and a few attractive grid services were selected. An assessment of the potential revenue for a water electrolyzers that could come from the participation to grid services was made considering the situation of today with the best way to combine H_2 supply for a primary value stream and to provide grid services [9]. Dynamic simulations with optimization of the operating strategy and of the size of the system were performed.

A second part of the analysis studied the potential future evolutions that could change the current picture. Simulations were done on prospective scenarios, highlighting notably the potential impact of electricity prices evolution on the results.

CONCLUSIONS

Similar grid services can be characterized by a generic testing protocol that should qualify an electrolyzer for a given grid service in most European countries trading this service. The requirements about dynamics of power ramping, stability and precision of reaching a given power, duration of keeping the new power level as well as power capacity if no aggregation is possible are characterising the different services. PEM and alkaline electrolyser systems have shown the capability of fulfilling the requirements of the services with proper adaptation of the system BOP. More services for which there is no clearly defined market and no prequalification procedures available will request similar performances of the electrolysers so that with the test results on the most popular services and some basic characterisation data of the system one can decide on the electrolyzer's capability. Providing grid services can contribute to an increased income of the electroyzer.

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