G0502

Unified and Standardized qualifying tests of electrolysers for grid services

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Abstract

Some grid services available for loads are well established in several European countries with the services and prequalification tests quite similar however with differences. In the future process of decarbonisation of the electricity but also other sectors hydrogen produced from renewable electricity in water electrolysers is believed to play an important role. However to be part of the grid service market electrolysers have to pass the prequalification tests. In order to ease the market entry of electrolysers demonstration of the capability of electrolysers to cope with these requirements should be helpful.

For this purpose the project QualyGridS establishes standardized testing protocols for electrolysers to perform electricity grid services. Protocols are trying to unify the different tests needed for different European countries. Some general basic qualification tests are defined from which the suitability of the system for any grid service can be derived. More specificially adapted to some well-established services like e.g. FCR, a-FRR (positive and negative) tests are defined integrating the requirements for Germany, France, Switzerland and other countries.

The protocols are validated for both alkaline and PEM electrolyser systems, respectively, using electrolyser sizes from 25 kW to 300 kW within the project showing the capabilities of today’s state of the art systems and extrapolation to larger systems. Testing protocols also include the review of existing and possibly set-up of new Key Performance Indicators (KPI) for electrolysers.

Introduction

With more and more renewable energy fed into electricity grids to achieve the goal of electricity decarbonisation high fluctuations of power input have to be equilibrated with measures for grid stabilisation like electricity grid services. These services apply in different European countries in in similar however still varying way.
Decarbonisation also has to be achieved in other sectors like mobility and heating and industrial applications. Hydrogen could be in the near future a vehicle to achieve this decarbonisation across the sectors. Hydrogen can be produced by water electrolysers using renewable energy or surplus electricity from the grid. Being flexible electricity consumers in the megawatt range electrolysers can also offer electricity grid services to improve their revenues.
Electrolysers are still in the process of being developed to meet the need: large capacity, low costs, high efficiency of energy transformation, highly dynamic operation. An overview of the present and future development status of water electrolysers is given in [1].
As a contribution to stronger market entry of water electrolysers combined with grid services the project QualyGridS works out testing protocols for electrolysers that perform grid services. The purpose of these testing protocols is to give the manufacturers and customers of electrolysers the reassurance that the electrolyser will be able to meet the grid services requirements.

1. Technical Requirements and Prequalifications for loads performing Grid Services

An overview of electricity grid services that might be accessible to water electrolysers was conducted collecting the technical requirements and prequalification procedures [2]. Loads are not in all EU countries permitted to participate in grid services. The grid services in the market are similar in most EU countries, however the exact technical specifications and prequalification procedures are defined by every country and show some variations.
The most common grid services are FCR (Frequency containment reserve, a-FRR (automated Frequency Restoration Reserve) and m-FRR (manually activated FRR). As an example of variations in the technical requirements the requested evaluation procedures for FCR in Germany, France and Switzerland are shown in figures 1-3. FCR is in most countries a symmetrical service requesting increase and decrease of power, the capacity requested is in the range of 1 MW and the maximum power change must usually be reached after less than 30 seconds. Some countries allow aggregation of several technical devices performing grid services together. By this the requirements for the single technical can be less demanding.
The grid services a-FRR and m-FRR are usually requesting higher capacity than 1 MW. In many cases they are assymmetrical, only requesting power increase or decrease. The power change rates for these services are less uniform across the countries. Again many countries allow for aggregation of technical devices.

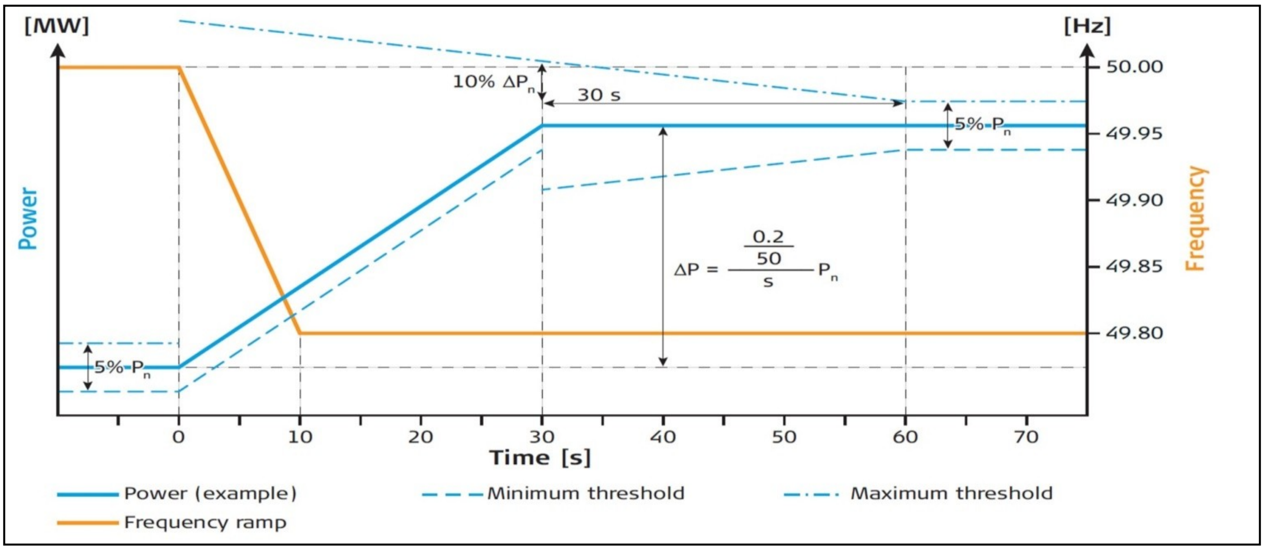

Fig. 1: FCR requirements Switzerland [3]

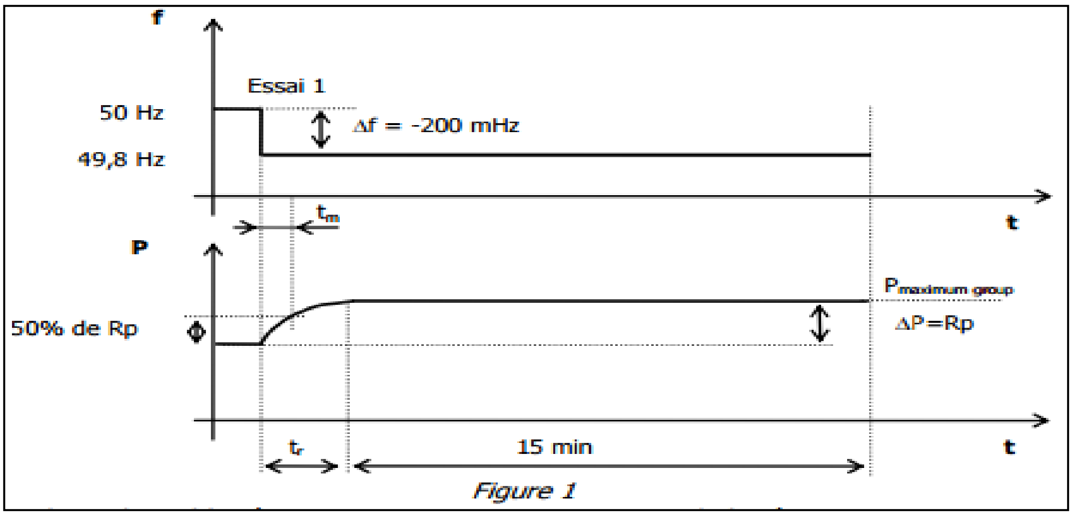

Fig. 2: FCR requirements in France [4] The pass criteria are: Non oscillating waveform, response time t_r < 30 sec, time t_m < 15 sec, the variation $\Delta P = R_p$ maintained for 15 min (after t_r)

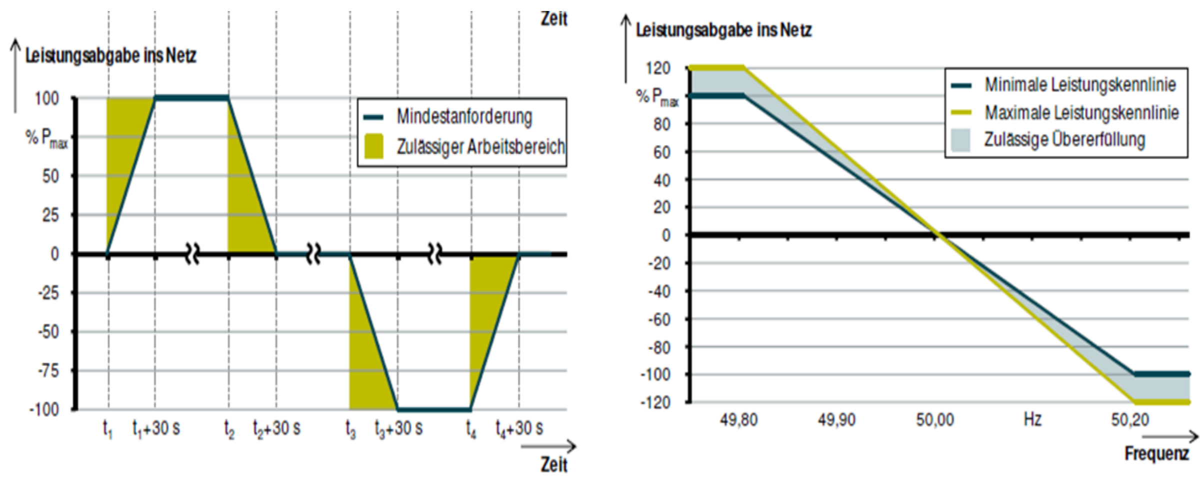

Fig. 3: FCR requirements for Germany [5]. The power must remain in the green respectively grey area

2. Unified Qualification tests

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The purpose of the project QualyGridS is to establish standardized testing protocols for electrolysers to perform electricity grid services. Due to the variations between countries the protocols are trying to unify the different technical requirements.

Some general basic qualification tests are defined from which the suitability of the system for any grid service can be derived. These tests determine the available power range of the electrolyser, the dynamics between the different states as well as the power stability in constant operation. From this it can be found which grid service could possibly be performed and subsequently the specific testing protocol of this grid service can be applied. For the most common grid services testing protocols and evaluation procedures are defined integrating the requirements for Germany, France, Switzerland and other countries. A device passing these tests should pass also the specific test of a single country because the pass criteria defined are defined in a range suitable for all the considered countries. On the other hand a device not passing the test might still be capable of performing grid services in some but not all EU countries.

The 2017 status of available documents on technical requirements and prequalification tests was taken as basis.

Examples of testing protocols and evaluation procedure suggested for unified FCR testing are shown in Figure 4. In a corresponding way protocols are suggested for a-FRR, m-FRR and RR (replacement reserve).

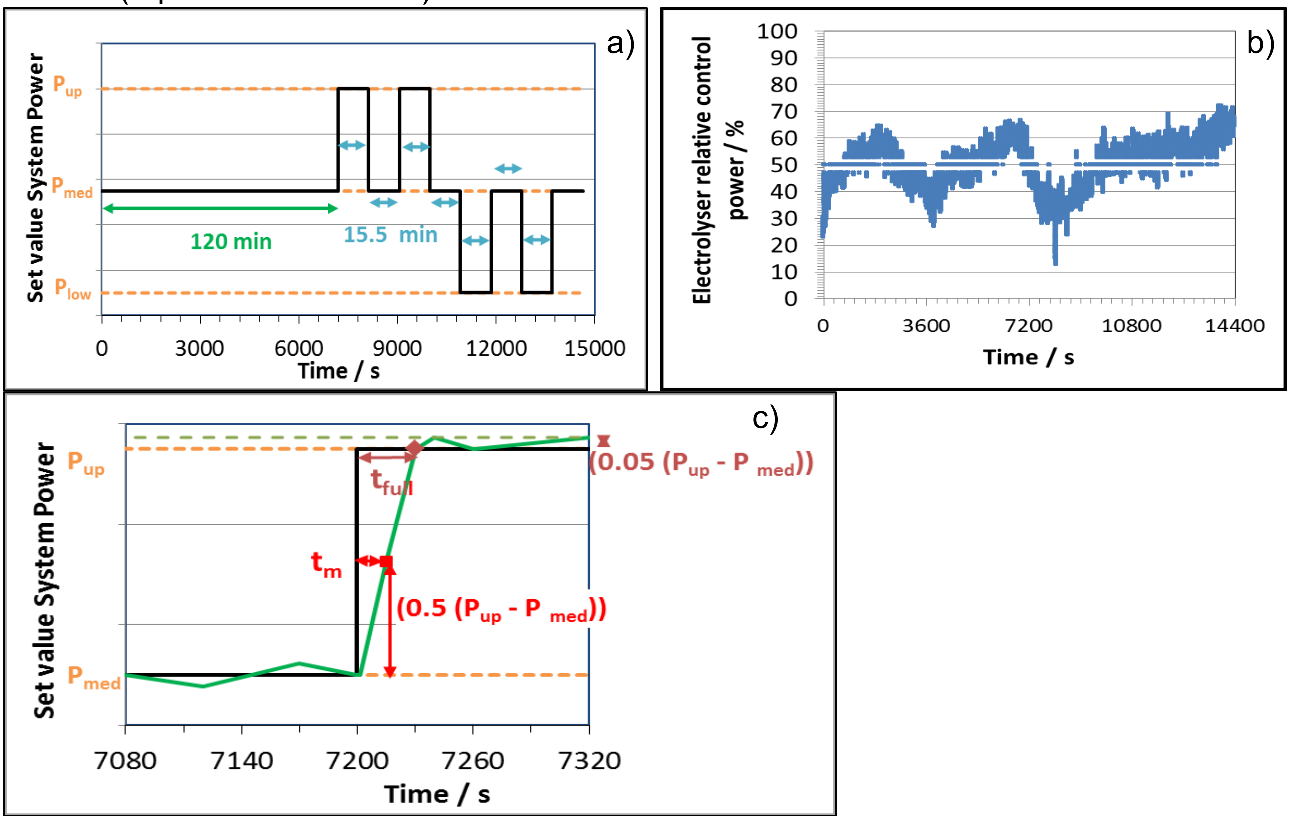

Fig. 4 QualyGridS suggested unified FCR testing protocols and evaluation. a) Testing protocol part 1 derived from prequalification procedures; b) Testing protocol part 2 derived from a real case of grid frequency input; c) Evaluation of activation times and stability. Pass criteria: t_m. ≤ 15 sec, t_{full} ≤ 30 sec, stability ≤ 0.05 (P_{up}-P_{med})).

3. Electrolyser Properties

Large scale water electrolysers available on the market today are usually alkaline electrolysers, a well established technique that has been used for producing industrial hydrogen for decades, however did not have to meet the requirement of dynamic operation. Recently the PEM (polymer electrolyte membrane) electrolyser technique has reached maturity to the megawatt range. These electrolysers usually show a higher efficiency, more dynamic operation and a smaller footprint. However today still every large scale electrolyser is made to the customer's application specific requirements. By adapting the BOP (Balance of plant) components requirements like dynamics, power stability, control strategy, gas purity etc. can be varied in a significant range. Besides the mentioned water electrolyser technologies also the high temperature electrolyser SOEC (Solid oxide electrolyser cell) is developed for hydrogen production. This technique with a high efficiency has to date not been demonstrated in the megawatt range, the development is continuing.

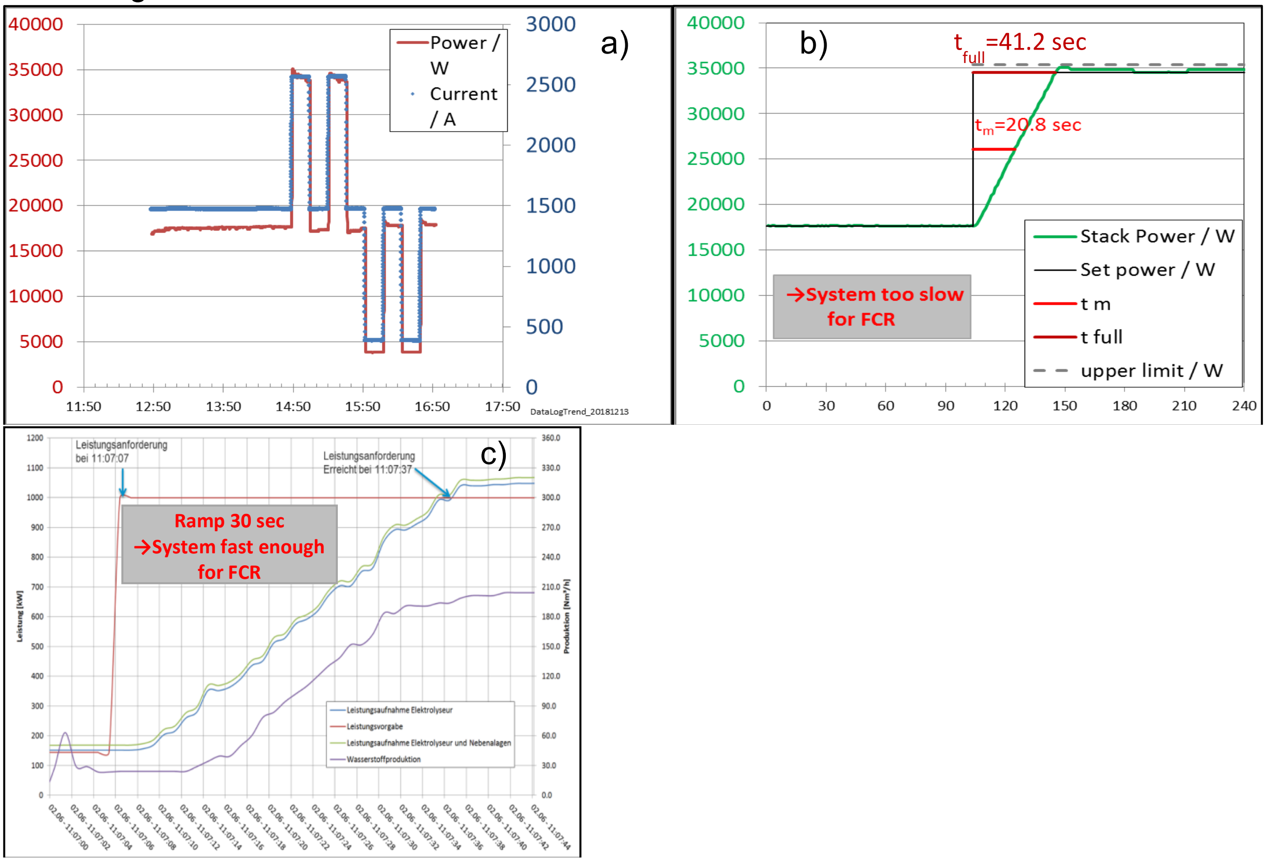

Figure 5: Ramp dynamics evaluation with PEM electrolysers with different power but same stack cell size: 50 kW experimental electrolyser at DLR, not designed for high dynamics and efficiency FCR testing protocol result, b) ramp analysis of the same electrolyser. c) 1.5 MW PEM electrolyser of Uniper, Hamburg designed for power to gas application with limited dynamics [6]

Within the QualyGridS project the suggested testing protocols are validated on both alkaline and PEM electrolyser systems, using electrolyser sizes from 25 kW to 300 kW. Thereby the project is showing the capabilities of today's state of the art systems with extrapolation to larger systems. Figure 5 shows as some testing result from the project results for an experimental PEM electrolyser system of 50 kW. For this system that was not designed for a very high dynamical behaviour and also not for high efficiency the dynamics would not be high enough for FCR but sufficient for FRR. Also the power stability for this system is not good enough due to many auxiliary devices with rather high power consumption being switched on and off during operation. However looking at the power increase ramp of a technical system, the 1.5 MW electrolyser installed in Hamburg Reitbrook, it can be seen that this system, also not being designed for high dyamics, meets the criteria for ramping speed and power stability. Other PEM electrolysers tested in the project also showed a reaction to power change requests within few seconds and would be capable of doing FCR. Also the tested 300 kW alkaline electrolyser at NEL that was specially adapted to high dynamics operation showed power changes within few seconds. Therefore with a suitable setup in BOP and control electrolysers are capable of doing all tested electricity grid services.

4. Conclusion / Outlook

As next steps the QualyGridS testing protocols will be updated with recent changes in the technical requirements and prequalifications published in the countries since 2017 (e.g. Germany [7]). A lot of changes are going on due to increasing shares of renewable energies in electricity, due to the EU decarbonisation requests as well as the ENTSO-E (European network of transmission system operators for electricity) [8] activities for unifying and opening the electricity grid markets in the EU.
The QualyGridS electrolyser testing protocols will be worked out as a technical standard and submitted to a standardisation organisation. The testing protocol curves are not necessarily specific to electrolysers. They could just as well be applied by other loads desiring to prequalify for a grid service. Therefore the use of these unified testing protocols also for other loads will be discussed.

References

[1] Study on low temperature water electrolyer technology status vs. applications including application in energy sector: *Development of water electrolysis in the European Union,* Luca Bertuccioli et al, http://www.fch.europa.eu/sites/default/files/study%20electrolyser_0-Logos_0_0.pdf
[2] Electrical Grid Service Catalogue for water electrolyser. D1.1, November 2017, http://www.qualygrids.eu/app/uploads/sites/5/2017/02/Deliverable-1.1-Electrical-Grid-Service-Catalogue-for-Water-Electrolysers-27-11-2017.pdf
[3] Swiss Grid, “Test for secondary control capability”, 2012, Apr, V2.1, accessed Aug. 2017. https://www.swissgrid.ch/dam/swissgrid/experts/ancillary_services/prequalification/D130422_Test-for-secondary-control-capability_V2R1_EN.pdf. Update accessed June 2019 https://www.swissgrid.ch/dam/swissgrid/customers/topics/ancillary-services/prequalification/3/D110426-test-for-primary-control-capability-V1R1-EN.pdf
[4] RTE, “Documentation Technique de Référence Chapitre 8 – Trames type”, V3, 2014, accessed Aug. 2017 http://clients.rte-france.com/htm/fr/mediatheque/telecharge/reftech/20-10-14_article_8-3__v3.pdf
[5] REGELLEISTUNG.NET, “Prequalification procedure for the provision and activation of control reserve” accessed Aug. 2017 https://www.regelleistung.net/ext/static/prequalification?lang=en
[6] Final report of the project “Kompaktes 1 MW-PEM-Wasserelektrolyse-System – Regenerativer Wasserstoff für Mobilität und Energiespeicherung (KompElSys) Septermber 2016 https://www.tib.eu/de/suchen/download/?tx_tibsearch_search%5Bdocid%5D=TIBKA

T%3A877878900&tx_tibsearch_search%5Bsearchspace%5D=tn&cHash=70057baab6abbc5909b52d2010ceea08#download-mark
[7] Revised prequalification requirements (FCR, aFRR, mFRR) - September 2018 Präqualifikationsverfahren für Regelreserveanbieter (FCR, aFRR, mFRR) in Deutschland ("PQ-Bedingungen") Stand: 23. Mai 2019 on https://www.regelleistung.net/ext/static/prequalification?lang=en accessed June 2019
[8] Network Code on Load-Frequency Control and Reserves (28.06.2013)

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