elyntegration

Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications

Final strategy plan for commercial exploitation of the results

DELIVERABLE 6.7

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Pablo Marcuello [1], Patrick Larscheid[2], Guillermo Matute[3], Laura Abadía[4], Vanesa Gil[4,7], Christian Immanuel Bernäcker[5], Jan Vaes[6]

[1] Industrie Haute Technologie (IHT)

[2] Institut für Elektrische Anlagen und Energiewirtschaft (IAEW)

[3] Instrumentación y Componentes (INYCOM)

[4] Fundación para el desarrollo de las nuevas tecnologías del hidrógeno en Aragón (FHA)

[5] Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM)

[6] Vlaamse Instelling voor Technologisch Onderzoek (VITO)

[7] Fundación Agencia Aragonesa para la Investigación y Desarrollo (ARAID), Spain

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1 EXECUTIVE SUMMARY

The research and innovation project “Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications“ (ELYntegration) focuses on the design and engineering of a robust, flexible, efficient and cost-competitive single stack multi megawatt high pressure alkaline water electrolyser.

A specific task in the framework of the project is to deal with the exploitation activities and project results after the project end. The project results that could be obtained during the project are from commercial point of view the development of materials (electrodes, membranes, stack) and systems (control system, BOP) which could be introduced in the market with an increased performance or commercial benefits. From scientific point of view, the consortium will also generate broad knowledge in the framework of demonstration testing protocols and accelerated stress tests, grid services, market analysis, business cases and grid regulation which could help in the deployment of the current technology.

The first result of this task has been the methodology defined in Deliverable 6.5 (public), agreed in cooperation with the European Commission through the “H2020 Common exploitation booster” programme in a specific seminar held by all the members of the Consortium.

Deliverable 6.7 defines the final strategy that the consortium will follow to pursue further exploitation of project results both from commercial and scientific point of view. The major conclusions of this deliverable are:

- Exploitation strategy is defined for the two major commercial results (MW HP AWE and C&CS)
- Identification of further collaboration routes depending on the validation step of each technical development
- Exploitation strategy for scientific results during 2019 and further research work in the field based on PhD in different partners beyond project ends.
- Business plan is defined for the two major commercial results (MW HP AWE and C&CS)

At the end of the project, the partners will define the final Intellectual Property Rights generated on the frame of ELYntegration and exploitable results linked to the project. This document summarising all this information will be included in the confidential report D 6.9.

2 OBJECTIVES

The research and innovation project “Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications“ (ELYntegration) is focused on the design and engineering of a robust, flexible, efficient and cost-competitive single stack multi megawatt high pressure alkaline water electrolyser.

In the framework of the project, different project results can be obtained from commercial and scientific point of view. Besides, those project outcomes can be the result of a cooperative work or just the contribution of one partner. The main rules to be followed by all partners in terms of the project results exploitation is defined in the Consortium Agreement.

The task 6.2 of ELYntegration project “Exploitation strategy and business plan for project results” has the objective of developing an exploitation strategy plan, including the identification of the exploitable results in the framework of the project focused on the commercial exploitation and on scientific results.

The objective of this report is to summarize the main work carried out in the task 6.2 related to the exploitation activities, defining the exploitation routes for commercial results, the planning proposed by each partner in terms of scientific results exploitation and the definition of a business plan for the two major commercial results.

This report along D6.5, summarizes the work carried out in the task 6.2 related to exploitation activities.

3 TASK STRUCTURE

In order to fulfil the task goals, there are different stages to accomplish as summarized below:

- Step 1: Identification of the methodology to be used (D6.5)
- Step 2: Identification of the exploitable results (D6.7)
- Step 3: Development of the final exploitation strategy (D6.7)
- Step 4: Final definition of IPR and exploitable results (D6.9)

Step 1 was successfully completed and Step 2 began in March 2017. For more details about the definition of the methodology please see D 6.5.

From that time the Consortium has been working on the other steps regarding the identification of the key exploitable results. This process has been carried out thoroughly according to the methodology on an iterative way between all the partners. The outcomes of this stage are the main results to be further commercialized, partners involved, risks, markets or countermeasures to be applied.

The exploitation strategy has been developed once the key exploitable results have been clearly identified. In this strategic plan, each exploitable result will have a specific business plan.

The final stage of this task will be the final definition of all Intellectual Property Rights developed during the project.

As this document has been defined as “public access”, the content of it will be in line with this classification granted.

4 EXPLOITATION STRATEGY

4.1 Commercial results

In the seminar held in March 2017 two main commercial results were identified by the consortium. During the second exploitation seminar held in September 2018 (Dresden) the potential exploitable results defined so far, were explained.

The first one is the "Multi MW high pressure alkaline electrolyser" for operation in a highly fluctuating power grid. This result is considered as the integration of each one of the technical developments carried out during the project:

- Cell topology
- Membranes
- Electrodes

In this first commercial result, there are included components developed by different partners which should be finally assembled in the stack configuration.

The second one is the "Control and Command System (C&CS)" designed to be operated properly providing grid services. This commercial result will be integrated by the electrolyser manufacturer in the whole system.

The following points summarize the key decision makers that will define the final exploitation strategy of each result.

4.1.1 Validation of the results on field

As this project is envisioned to have at the end a close gap with the commercialization phase (TRL 7), it is considered that the technical developments must be validated at real operation conditions (i.e. operation pressure and temperature, current density, etc) and market sizes (i.e. stack dimension) as a first stage to consider the inclusion in the final commercial result.

Based on this condition, there are different approaches that can be pursued to further exploit the commercial result:

1. The technological development is fully validated at commercial conditions: in that case if it is interesting by the owner of the development and the body in charge of the commercialization, some bilateral commercial agreement can be formalized between the different partners involved.

2. The technological development has not been fully validated at commercial conditions: in that case it cannot be considered that the development can be further commercialized and therefore some additional validation stages must be considered. In that case, some different approaches related to further collaboration will be evaluated:

    a. Private funding -> on the basis a bilateral agreement between the developer and end-user

b. Public funding -> on the basis of a common project with other partners in the work of a cooperative project

4.1.2 Industrial Property Rights

This point will be further analysed in D6.9 but as a general rule, it is defined here below the situations that could happen related to IPR.

1. If the development is infringing or it can infringe any patent in force, the developer must find a solution to the potential dispute before starting to consider if such development can be further commercialized. Normally, the solution can be reached by a license agreement between the organizations involved. If such dispute cannot be solved, the developer should find another way of further results commercialization or refuse definitively the development.

2. If the development is not infringing any patent in force, the developers are free to decide if such development will be patented or not. In the case of joining results, the procedure is defined in the Consortium Agreement.

Each result and each developer will consider, taking into account the nature of the development and the commercialization possibilities, the patentability options and the level of protection desired.

4.1.3 Industrialization process

As commented in section 5.1.1, a condition so that a development can be considered as further commercialized by the electrolyser manufacturer is that such development has been tested at real operation conditions and market size.

After that, an important point to consider after the ones commented in 5.1.1 and 5.1.2 is to assess if the development already tested and free of IPR infringements can be further industrialized.

For doing that, each developer must identify the requirements of the potential industrial partner interested in the scale-up and industrialization process. In certain cases, the developer and the industrialization body are the same, making easier the identification and the finding of the industrial player.

During the industrialization assessment, different options can be identified:

1. The industrial partner considers that the industrialization process is not possible or it is not feasible at a reasonable cost for the market size requested. In that situation, the development can be used in other different market to valorise the results or it can be finally refused.

2. The industrialization process is possible at a reasonable cost and the industrial player is interested in the further commercialization. In that situation, a new component/equipment can entry to a certain market

3. The industrialization process is possible at a reasonable cost but the partner is not more interested in the commercialization or further development. In that situation, if there are other organization with potential interest in the development, that body should achieve an agreement with the development owner.

4.1.4 Bilateral agreements

In certain cases, bilateral agreements already in place before the ELYntegration project will determine the further exploitation activity of some outcomes.

In that case, the electrolyser manufacturer IHT and the C&CS developer INYCOM have been working together in previous projects and pursuing common commercial activities.

For new developments, commercial supply agreements could be possible between the developer and the end user.

4.1.5 Market evolution

It is possible that the exploitation strategy is affected by the market evolution and sales expectations.

In a situation of low sales expectations, a development that could be further commercialized and industrialized can lose the interest of the industrial partner due to the low potential revenues that could be obtained.

4.1.6 Market structure

The exploitation strategy will be also determined by the concurrence of other competitors offering similar products than the development achieved.

In that situation, the partner interested will define properly what strategy must be followed, attaching small markets, having an aggressive price policy or trying to look for synergies or alliances with the potential competitors.

It will be also important that there are no any legal barriers that could hinder the fast market deployment.

4.1.7 Market risks

A market risk analysis is mandatory to define the proper approach for exploitation strategy and to determine if the development has possibilities to be further commercialized providing revenues to the owner.

There are different risks that must be taken into account, such as:

- Other technologies competing in the same market
- The expected selling price doesn't match with the market demand
- The customer interest is lower than expected
- Effects of regulation changes
- Deployment time is longer than expected and financial/cash problems could appear

4.2 Scientific results

The exploitation of the scientific results has already started during the project course while the first project results have been obtained. Each partner is free to decide about the scientific exploitation strategy, deciding where to carry out the dissemination and the target groups that wants to be matched.

All the dissemination activities carried out until now have been done respecting the rules defined by the Consortium Agreement. The same agreement will govern during the exploitation activities after the project ends.

In the following points, it is summarized the exploitation activities related to scientific results carried out by each partner until now and the plans for the future as already discussed during the second exploitation meeting held in September 2018 (Dresden).

4.2.1 FHA

FHa, as coordinator of the project, has encouraged and participated in an important number of events in order to disseminate findings and main results of the project. Some of the most relevant events where scientific projects results were presented are described below.

At the beginning of the project, FHa performed overview presentations to make known the objective and scope of the project and partners involved (Iberconappice 2016 (Spain), World Hydrogen Energy Conference 2016 (Spain)). During 2017, the work developed on phyton to simulate the behaviour of the stack and the whole system while running under dynamic conditions was presented at Iberconappice 2017 (Spain). Running in parallel, accelerated stress tests (AST) were designed and months later, tested on the pilot scale test bench. The methodology followed through the process of design (showed in Iberconappice 2017) and the most relevant results were then presented in the European Hydrogen Energy Conference 2018 (Spain) and the International Hydrogen and Fuel Cells Conference 2018 (Norway). For each of them, updated results and new findings were presented as agreed by the whole Consortium. In 2018, it was an honour that the latest ELYntegration results on degradation and lifetime of novel membranes for water electrolysis technology providing grid services were shown during the World Hydrogen Energy Conference in Brazil as a keynote lecture invitation.

For 2019, one of the main objectives is to present the latest AST results on pilot scale test bench and dynamic testing conditions tested on the industrial scale test benches at the World Hydrogen Technologies Convention in Tokyo. Several publications with the most relevant project results are planned to be released during 2019.

4.2.2 VITO

ELYntegration's approach for separator membrane development and preliminary results were presented at the First International Conference on Electrolysis (ICE; Copenhagen, Denmark, 2017). Further results from membrane development, AST and characterisation *post-mortem* were included in several communications at conferences presented by FHA, such as the European Hydrogen Energy Conference 2018 (Málaga, Spain), the International Hydrogen and Fuel Cells Conference 2018 (Trondheim, Norway) and notably the World Hydrogen Energy Conference 2018 (Rio de Janeiro, Brazil).

Two scientific publications are under preparation to be released during 2019, in collaboration with FHA, on the membranes developed and tested under the AST protocol.

4.2.3 IFAM

ELYntegration created a lot of results in the field of catalysis and electrode production. The scientific results were presented at the 21st WHEC in Zaragoza (2016), at the Hannover Fair (Hydrogen and Fuel Cells exhibition, 2017), at the 1st International Conference on Electrolysis in Copenhagen (2017), at the 2nd ELYntegration Workshop (2018) and will be published in an open access journal in 2019.

4.2.4 IAEW, RWTH Aachen University

The main results of the scientific work done by IAEW has been summarized in three public deliverables (2.1, 2.3 and 6.4). Besides this, IAEW has presented the main results at conferences such as "HYPOTHESIS XII" (2017, Syracuse, Italy) and "Symposium European Grid Service Markets" (2017, Lucerne, Switzerland). The most significant project results are described in a paper with the title "Potential of new business models for grid integrated water electrolysis" that was submitted to and accepted by "Renewable Energy – An International Journal" (doi: 10.1016/j.renene.2018.02.074). Additional dissemination of results related to the work undertaken in task 2.3 and 6.1 is pursued.

While not directly linked to the project ELYntegration, PhD candidates at IAEW are currently working on research topics related to the integration of water electrolyser into power systems dominated by renewable energies and will carry on to do so in the future. These topics include co-simulation strategies for optimizing the natural gas and power system infrastructure coupled by water electrolyser as well as macroeconomic evaluation of water electrolyser applications for future energy systems.

4.2.5 INYCOM

In terms of exploitation of results, INYCOM is the provider of the control and communication system for the IHT electrolyser. Both companies work in partnership so that this C&CS enables to deliver an electrolyser with the following advanced features:

- Remote control and monitoring through a dedicated SCADA displaying parameters of operation and main output KPIs reached.

- Smart operation in terms of energy efficiency and remuneration from grid services provision

- Predictive maintenance through data analysis to reduce the frequency of preventive measures and eliminate corrective actions.

In terms of scientific progress, INYCOM has presented the paper "Development of a control and communication system with functions of predictive maintenance and smart operation for the provision of grid services by an alkaline electrolyser" to Iberconappice 2017 Congress[1]. Besides,

[1] S. Ayuso, G. Matute, L. M. Blasco, I. Lalaguna, E. Morales, V. Lapuente, M. Rubio, "Desarrollo de un sistema de control y comunicación con funciones de mantenimiento avanzado y operación inteligente para la provisión de servicios de red por un electrolizador alcalino", Hidrógeno, Congreso Iberoamericano de Hidrógeno y Pilas de Combustible 2017 [available at]: https://appice.es/Congresos/H2-Iberconappice2017.pdf

Guillermo Matute is PhD candidate by the University of Zaragoza in the subject “Analysis of the potential and recommendations for multi MW water electrolysers to benefit from the provision of grid services for frequency adjustment while generating hydrogen for different end uses in the EU”, which is closely related to ELYntegration’s progress in WP6. As part of this thesis, a paper has been submitted to the International Journal of Hydrogen Energy (IJHE) and is currently under evaluation.

4.2.6 IHT

IHT, as electrolyser manufacturer, has been more focused in the exploitation of commercial results rather than the exploitation of scientific results. Anyway, IHT has contributed to them by reviewing all the communications sent in advance by the partners to avoid publishing some confidential information that could hinder the commercial exploitation activities of such results.

5 BUSINESS PLAN FOR EXPLOITABLE RESULTS

As defined in the Description of Action, each exploitable result must contain a business plan to try to shorten as much as possible the time until this new product is on the market. In the following points it is summarized the main points of a business plan for each exploitable result identified.

5.1 Multi MW high pressure alkaline electrolyser

5.1.1 Value creation

Development of a high pressure alkaline electrolyser in the range of the MWs size. The electrolyser is able to work under high dynamic conditions, specially providing grid services such as FCR or aFRR.

The major advantages are the high production rate due to the stack size, improved with an increase of the current density. Also the fast response during operation to offer flexibility to those customers requested for it.

The CAPEX for MWs size is in the range of the FCH-JU expectations for 2020.

5.1.2 Industries and end-user customers

The markets to be reached are those already identified during the ELYntegration project in WP2 (D2.3) and WP6 (D6.4):

- Industry
- Mobility
- Energy (P2G)

The strategy and time line to try to get into each separate market will be different and it will depend mainly in the maturity of the market, existing customers, competitors and the regulation in force.

Classified by the time line, industry market at MWs size could be considered as short term action. Meanwhile for the moment MWs projects at mobility and energy sector (P2G) are more linked nowadays to funded projects and they are envisioned to the mid-long term (starting from 2020).

The target groups in each case will be reached with the following procedure:

1. Electrolyser manufacturer identifies potential customer or group of industries (food, beverage, chemical, refineries, etc) that could be in position (depending on the size and location) to be interested on the production of H2 by MW high pressure alkaline electrolyser.
2. The first contact is done directly by the electrolyser manufacturer, avoiding intermediaries who could provide some incorrect messages. If the first contact is positive, some info related to the development of business case is asked for (electricity price, hydrogen demand, hydrogen quality required, pressure required, cogeneration possibilities, existing facilities, etc). If this info is provided, the electrolyser manufacturer configures the business case for the customer.

3. The business case is sent to the customer for their internal assessment. The assessment time at customer side depends on the type of company, amount of investment, production planning, financial risks, market uncertainties, etc.
4. If the customer gives green light to the business case, the electrolyser manufacturer provides a detailed quotation and delivery time.

In certain cases, the customers are the ones who contact directly to the electrolyser manufacturer with a consolidate business case. Therefore in those cases points 1 to 3 are not needed and the electrolyser manufacturer just sends a formal quotation that satisfies the requests defined by the customer.

5.1.3 Management of internal resources

The resources that must be available to carry out the business plan can be classified in different groups:

- Management and administration
- Business development and planning strategy
- Engineering
- Production
- Quality assurance
- Sales and post service

The management and business development departments define the strategy to follow to reach a certain customer or group of industries. Once defined the specific strategy per customer, the business development department gets in contact with the customer.

If the feedback is positive, the business development and engineering department works together to build up the business case that has to be sent to the customer.

If the project moves forward, the business development and management departments prepare the final quotation to the customer.

In case that the customer makes official the purchase order, the engineering starts with the design phase to start with the procurement process. The manufacturing involves different stages and it is done by the production department.

The process finishes with the quality assurance, factory acceptance test and final delivery to the customer. Once commissioned on field, the sales and post-service department gest in contact with the customer in case that some problems could happen.

The number of employees in each department will be defined of course by the market size and opportunities that can be achieved. High personnel costs in markets still relatively not mature can hinder the possibility of further business potentials.

5.1.4 Risk assessment

The risk assessment is a part mandatory in the deployment of a business plan. The risk assessment is carried out by different internal departments such as management, business development or engineering. The risks evaluated are similar to the ones shown in point 4.3.

The contingency plan agreed internally must take into account those risks categorized as more dangerous for the business plan deployment.

5.1.5 Financial and funding resources

The business plan must contain with the needed financial resources to carry out the work committed. This financial resources can be fed from internal revenues or external funding by private investors.

5.2 Control and Command System (C&CS)

5.2.1 Value creation

In the recent years, most of C&CS related to FCH technologies have been limited to keep installations operating inside safety thresholds and compile limited number of signals needed to check the status of the system.

In the case of AWE, some remote monitoring and control functions have been implemented by OEMs by means of SCADA systems which allow to manage FCH installations more efficiently as a whole, but there is still the challenge of studying how to reach the best possible performance to bring extra benefits considering the possibility to provide grid services and take advantage of volatility of energy markets.

In the context of ELYntegration, the C&CS developed has been improved to pave the way for the following short-term implementations needed in the current energy markets, adopting a global approach covering not only the classical control features but also providing added value characteristics to the MW HP AWE technology which go beyond state of the art systems.

5.2.2 Industries and end-user customers

INYCOM aims at addressing the following markets together with IHT in the field of AWE:

- Industrial applications (e.g. chemical, petrol industry)
- Hydrogen refuelling stations
- Power to gas for injection of hydrogen into the gas grid.

These markets will be addressed as detailed by IHT in section 5.1.2 in the field of AWE.

Besides, due to the horizontal character of ICT, INYCOM has applied part of the knowledge gained in the field of control and communication of AWE in ELYntegration to apply it to the following fields:

- Hybrid mobility based on FC and battery, where INYCOM is exploring the market of ships offering an overarching C&CS to govern the whole powertrain.
- HVAC industry, where INYCOM is developing a C&CS with predictive maintenance and smart operation functions for air handling units (AHU) to allow the manufacturer the provision of improved predictive maintenance to their customers as well as a better knowledge on their product.
- Smart grids. INYCOM is starting a new H2020 project in 2019 in the field of control and communication of microgrids with interaction with energy markets to allow prosumers to benefit from aggregation. An advanced C&CS for a

microgrid will be developed to test the models already developed by INYCOM in the previous project P2P Smartest[2].

- Railway industry. INYCOM has created MainRail[3] solutions, a young startup oriented to a product (SCADA based) which is able to schedule maintenance of railway infrastructure with a reduced amount of interventions to operators via the data analysis of weather, traffic and other measures taken on the field.
- Automotive and manufacturing industry, with lean manufacturing solutions and products devoted to increase capacity, availability, performance, quality and OEE in assembly lines based on SCADA and MES systems with remote control and monitoring functions.
- Agro-food industry, where INYCOM is establishing key partnerships right now to introduce SCADA and MES systems to increase yield and food quality & safety to improve processes in food processing companies.

5.2.3 Management of internal resources

INYCOM has two departments in charge of the developments required to improve the C&CS:

- **R&D department** with senior project managers in charge of: (a) managing ongoing projects related to C&CS for different applications, (b) exploring pathways for exploitation towards different markets, (c) creating new partnerships and commercial relationships.
- **Innovation, Engineering and Integration (i3) department** with senior technicians with large background in process control, data analytics and representation, field instrumentation and power electronics. This department is in charge of the design, development, commissioning and testing of C&CS.

Once the technology and knowledge involved in the C&CS is mature and there is more replication in other markets, then the natural step is to involve the business units at INYCOM, including the ICT business unit and the power electronics business unit.

5.2.4 Risk assessment

Currently, the risks related to the C&CS in the field of AWE are related to the market. As presented above, the C&CS can find replication in a faster way in other sectors, but the FCH markets are in a phase of preliminary deployment which delays developments.

Other barriers are:

- **Regulations** in different countries, especially in the field of grid services provisions as they vary from country to country and also between grid operators. Also, regulations may differ in relation to the assembly of the C&CS cabinet depending on the target plant where it is located.
- **Customer needs** are also important, as some of them may not appreciate the added value of an advanced C&CS and may opt for very basic features such as control and monitoring of the machine.

[2] http://www.p2psmartest-h2020.eu/
[3] http://www.mainrailsolutions.com/

- **Cost of WE technology**. AWE is the most cost competitive technology within WE, but it is still required to decrease CAPEX and OPEX so that the product as a whole finds more market acceptance.
- **Heterogeneity of projects**. Projects may not be similar between them, which requires adaptations and modifications in the C&CS. This implies different regulations, communication protocols, hardware requirements, etc.

5.2.5 Financial and funding resources

INYCOM, supported by IHT, are investing their own resources to keep developing the C&CS in ELYntegration so that it incorporates the features described in section 5.2.1.

6 CONCLUSIONS

The ELYntegration Consortium has been working on the exploitation activities based on the methodology proposed by the European Commission as part of the H2020 Common Exploitation Booster programme as explained in D6.5.

The major conclusions of this deliverable are:

- Exploitation strategy is defined for the two major commercial results (MW HP AWE and C&CS)
- Identification of further collaboration routes depending on the validation step of each technical development
- Exploitation strategy for scientific results during 2019 and further research work in the field based on PhD in different partners beyond project ends.
- Business plan is defined for the two major commercial results (MW HP AWE and C&CS)