Business background analysis for a controlled hydrogen-based microgrid

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***Abstract*—A business study is developed for a marketable hydrogen-based micro-grid powered by a mix of renewable energies. This micro-grid is designed to be installed in an isolated location. It produces hydrogen which can then be consumed in a fuel cell when energy is required or used in a fuel cell electric vehicle. The economic study is divided into three sections: first, a brief introduction of the marketing of hydrogen-based microgrids is given. Then an evaluation of the components of the Business Model Canvas (BMC) is done for the case of this marketable microgrid. Finally, a business plan is done to summarize the economic study of the microgrid and the possibilities of marketing it, showing the possibility of implementing this type of controllers in microgrids based on hydrogen.**

Keywords—electrolysis; hydrogen-based microgrid; marketing; business plan

I. INTRODUCTION

The modern concept of microgrid is highly promising as a solution to the problem due to the future scarcity of fossil fuels in conventional power generation. It is also effective against environmental impacts of existing generating systems [1]. Among the possible energy storage systems, those based on hydrogen production by electrolysis and subsequent utilization in fuel cells offer an attractive alternative to conventional systems (water pumping, compressed air, batteries, etc [2].

The use of hydrogen energy storage systems for grid support can be more accurately conceptualized as enabling the appropriate allocation of electrical resources to high-end markets, while improving overall system sustainability and resiliency and lowering supply costs. Electrolysis units can provide ancillary grid services [3]; renewable hydrogen can be stored and it can be used in multiple transportation and industrial end-use markets. When hydrogen is supplied to zero-emission fuel cell electric vehicles (FCEVs), the resulting revenue is higher than that from supplying grid electricity because of the higher market price per unit of energy for transportation fuels [4].

II. HYDROGEN-BASED MICROGRID

The proposal here consists in the evaluation of the possible commercialization of a hydrogen based microgrid, (as depicted in Figure 1). For the case of the one proposed in Figure 1, the energy sources are green and sustainable (see H2OCEAN project in (http://h2ocean-project.eu/). They are renewable and can easily be obtained in coastal locations [5]. The electricity produced is sent to a set of electrolyzers that transform water (H_2O) into hydrogen (H_2). Moreover, for certain times when available renewable power is not enough to operate the electrolyzers, a battery and an ultracapacitor are included to supply energy to the electrolyzers. Finally, the hydrogen produced can be given to users to be used as input in fuel cells or for different needs [6].

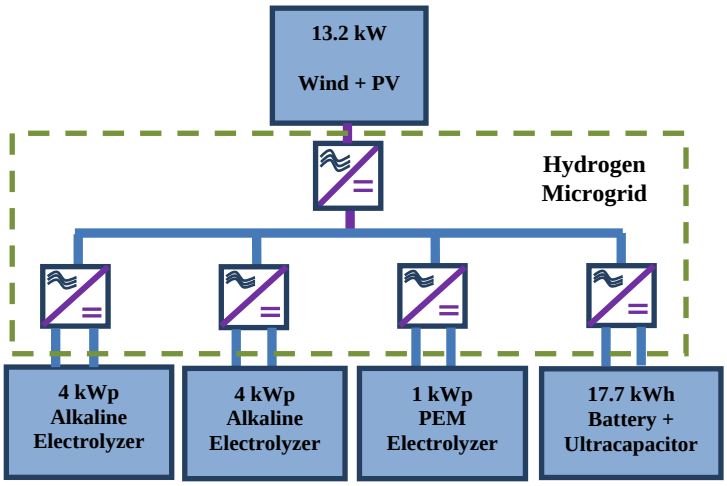

Fig 1. Hydrogen-based microgrid proposed in this case study.

In this paper, the commercialization possibility of the control system designed in [7] for the hydrogen-based microgrid is considered. The goal is to create a company and design a business plan for it. The proposed company would have the sale of the hydrogen-based microgrid controllers as its business model. The name of the proposed company is HyRenCon (Hydrogen Renewable Control).

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III. BUSINESS MODEL CANVAS

The purpose of this section is the evaluation of the Business Model Canvas (BMC) in the case of marketing this smart micro-grid. This BMC reflects systematically on the business model and comprises different aspects, such as selecting the key partners, the key activities, the value proposition, the customer relationship, the customer segment, the key resource, the distribution channel, the cost structure and the revenue stream.

The Business Model Canvas is a strategic management and lean start-up template for developing new or documenting existing business models [8]. It is a visual chart with elements describing a firm or product's value proposition, infrastructure, customers, and finances [9]. It assists firms in aligning their activities by illustrating potential trade-offs. The Business Model Canvas was initially proposed by Alexander Osterwalder, based on his earlier book on Business Model Ontology. Since the release of Osterwalder's work in 2008, new canvases for specific niches have appeared.

Formal descriptions of the business become the building blocks for its activities. Many different business conceptualizations exist; Osterwalder's work and thesis [10] propose a single reference model based on the similarities of a wide range of business model conceptualizations. With his business model design template, an enterprise can easily describe the business model.

The components of a canvas assessment for the proposed HyRenCon company are as follows:

A. Offering

1) Value Propositions: These are the collection of products and services a business offers to meet the needs of its customers. According to Osterwalder [10], a company's value proposition is what distinguishes it from its competitors. The value proposition provides value through various elements such as newness, performance, customization, "getting the job done", design, brand/status, price, cost reduction, risk reduction, accessibility and convenience/usability. The value propositions of HyRenCon are the design of a controller of a hydrogen-based microgrid [7], which improves equipment life by up to 30%. This type of microgrid allows energy self-sufficiency without dependence on connections and disconnections to the electricity grid or from diesel or other fuels, since it works with renewable energies. Moreover, it is adaptable to many types of renewable energies (wind, solar, marine…).

B. Customers

2) Customers Segments: To build an effective business model, a company must identify which customers it tries to serve. Various sets of customers can be segmented based on the different needs and attributes to ensure the appropriate implementation of corporate strategy that meets the characteristics of the selected group of clients. In the case of HyRenCon, the customers can be companies that manufacture electrolyzers or fuel cells, R&D companies, universities and technology centres. Examples of these customers can be: Abengoa, Tecnalia, Ariema, Repsol, Iberdrola, Panasonic, Vaillant, Viessmann, Elcore, etc. 99% of the market is located in countries such as the USA, Japan, Sweden, Denmark or Germany.

3) Channels: A company can deliver its value proposition to its targeted customers through different channels. Effective channels will distribute a company's value proposition in ways that are fast, efficient and cost effective. The channels of our proposal can be fairs (Construmat, Expoquimia, WHEC…), business visits and public announcements (H2020).

4) Customer Relationships. To ensure the survival and success of any business, companies must identify the type of relationship they want to create with their customer segments. The relationship between HyRenCon and its customers can be personal assistance (assistance in a form of employee-customer interaction) via Skype in order to check the controller for a certain period of time.

C. Infrastructure

5) Key Activities: These are the most important activities in executing a company`s value proposition. In the case of HyRenCon, it would be the recruitment of a technician, hiring a courier company, the coupling of the meteorological predictions with the PLC (Programmable Logic Controller) and contact with customers via Skype, phone, etc.

6) Key Resources: These are the resources needed to create value for the costumer. They are considered an asset to a company, as they are needed to sustain and support the business. In the case of HyRenCon, they are the control algorithm patent and human resources such as PLC programming.

7) Partner Network: In order to optimize operations and reduce the risks of a business model, organizations usually cultivate buyer-supplier relationships so they can focus on their core activity. In the case of HyRenCon, these partners could be the University of Valladolid, the CNH2, or Technological centres such as CARTIF or CIDAUT. The controller can be tested and checked in these institutions, which receive feedback and apply the knowledge.

D. Finances

8) Cost Structure: This section describes the most important monetary consequences while operating under different business models. The expenses of HyRenCon are mainly the purchase of PLCs, the staff (technical installer), the local rent, web domain, packaging, transportation and shipping.

- Characteristics of Cost Structures: fixed costs (costs are unchanged across different applications), variable costs (depending on the amount of production of goods or services), economy of scale (costs go down as the amount of goods are ordered or produced) and economies of scope (costs go down due to incorporating other businesses which have a direct relation to the original product). HyRenCon follows a type of economy of scope. A study of the costs is developed in the Business Plan.

9) Revenue Streams: This is the way a company makes income from the customers. In the case of HyRenCon, the way to generate a revenue stream is to sell assets, which is the most common way (selling ownership rights to a physical good). HyRenCon sells controllers programmed and installed in a PLC. After-sales service and patent income would also be considered.

IV. HYRENCON BUSINESS PLAN

HyRenCon proposes the commercialization of an advanced controller for an autonomous energy system based on an electrolyzer and fuel cell (see Figure 2). It makes the life of the components last up to 30% more, being a completely innovative product.

Fig 2. Example of a hydrogen-based microgrid

(https://www.curbed.com/2016/1/22/10844376/solar-powered-hydrogen-home-thailand)

This microgrid allows energy self-sufficiency without relying on electrical connections, diesel or other fossil fuels as the energy comes from renewable sources. Moreover, the controller can be adapted to any type of renewable energy, whether wind, hydraulic, solar, marine…

Figure 3 shows a smart house powered by renewable energies and a hydrogen-based microgrid, located in the CNH2 in Puertollano, Spain.

Fig 3. Smart house powered by renewable energies and a hydrogen-based microgrid in the CNH2, Spain

The business model of HyRenCon is based on selling advanced controllers for hydrogen-based microgrids. These controllers are programmed in a PLC which is coupled to the microgrid. The revenues are generated by the sales of the PLCs (see Figure 4). In addition, there is an intellectual property registry on the design of the software algorithm of the controller [7].

Fig 4. Example of a Siemens PLC controller

The possible customers are the companies that manufacture and produce the components of the hydrogen-based microgrid (electrolyzer and fuel cell). In addition, potential clients may be technology centres, energy companies and academic institutions such as universities and institutes.

V. MARKETING PLAN

The value proposition would consist of the sales of an advanced controller programmed in a PLC that manages the connections and disconnections of the components of the hydrogen-based microgrid, taking into account meteorological predictions and the control algorithm developed in [7]. These predictions give the amount of green energy predicted in advance that can be supplied to the hydrogen-based microgrid.

This product would be sold to the possible customers that manufacture the components of the hydrogen-based microgrid (some have been detailed in the description of the business model). The components of the microgrid currently cost around 2,000 $/kW [11]. The final user would be energy self-

supplied by installing this type of microgrid at home; therefore, it would not be necessary to be connected to the electricity grid. The costs of the electrolyzers and fuel cells are expected to decrease over the years [12].

Hydrogen is considered the main energy vector in the future. The principal reason is because it constitutes 75% of the visible matter of the universe [13], and most of all because it depends on clean and sustainable energy consumption. It can also be used in fuel cell electric vehicles which are already marketable (Toyota Mirai, BMW i8, etc).

One of the main problems of this type of clean technologies is that if the demand is low, the electrical surplus is lost as there are no real solutions to storing this energy. There are three main options to store the energy: water elevation, air compression, and chemical storage such as hydrogen and methane. Hydrogen is considered the best option when energy requirements are high [14].

Nowadays, many industries produce hydrogen, especially petrochemicals and refineries, but these types of technologies are not green and they emit greenhouse gases such as CO_2, SO_2 or NO_2. Thus, the hydrogen produced by these techniques may contain impurities. Therefore, electrolysis has been chosen as the technology to produce hydrogen in a sustainable way. Hydrogen has different commercial uses. In this business plan, we focus on the use of hydrogen in a fuel cell to supply energy requirements in an isolated house.

There are two main customer markets for hydrogen production: one is renewable energy plants and the other is fuel cell electric vehicles. Hydrogen with pure hydrogen is required to minimize the risk of explosion. Hydrogen produced by renewable energies fits perfectly with the industry's effort to reduce greenhouse gas emissions. There is a tendency in Europe that focuses on the research and development of the electric vehicle, whereas in Asia there is more interest in the hydrogen car. Batteries of electric cars take a long time to charge and their autonomy is not very high. On the other hand, the operation of hydrogen cars is equal to a gasoline or diesel car [15].

The idea of designing an advanced control in a hydrogen-based micro-grid began in 2013 (see H2OCEAN project). Over the years, the original microgrid developed in the H2OCEAN project changed into a domestic device because it was considered that an autonomous microgrid supplied by renewable energies could be useful at a household level with the aim that any final user could self-supply with clean energy.

Much great research work is being done on the validation and analysis of the control algorithms, shown in many scientific contributions [7]. In addition, the functionality of the controller has been checked in the microgrid laboratory at the National Hydrogen Center (CNH2) in Puertollano, Spain.

On the other hand, there are several handicaps that HyRenCon must confront. The most important is a lack of its own resources to be financed. Another handicap is the limited financial knowledge that the promoter team has and the uncertainty of the hydrogen-based economy in the long term. Many studies say that 2050 is considered as the date in which hydrogen will be used mostly in the world instead of fossil fuels, but they are still hypotheses [16].

A. SWOT analysis

SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis is a structured planning method that evaluates some elements for an organization, project or business venture [17]. It is the acronym of strengths, weaknesses, opportunities, and threats. The SWOT analysis for the case of HyRenCon is as follows:

- Strengths
  High theoretical and technical knowledge. Experience of the hydrogen sector (especially national as the promoter team of HyRenCon has participated in congresses, meetings and fairs with related companies in the sector).

- Weaknesses
  Lack of initial resources (economic, logistic, etc). No contact with companies that may be interested in the product as they are located mostly outside Spain and the way they work. Lack of contacts with these companies.

- Opportunities
  Although there is some uncertainty about the future of the hydrogen economy, we have studied its evolution over the last few years and it has been proven to be a promising market, especially in Scandinavian countries, Japan and the USA. Local governments are motivated from the European Union to restrict fossil fuels in the coming years (regulating the circulation of fossil fuel cars in cities such as Madrid, Paris or London).

- Threats
  The main problem could be the lack of costumers due to the fact that hydrogen-based microgrids are not common in the short and medium term. In addition, the possible customers could develop analogous controllers in their own R&D departments, or they could be interested in the proposal of HyRenCon and integrate it into their manufacturing process.

The main objective of HyRenCon is to be a leading company in the control of hydrogen-based microgrids. For this, the promoter team has extensive theoretical knowledge and has been working to complete this thesis manuscript which deals with the design of the advanced control system. In addition, the controller has been tested in a microgrid laboratory (CNH2 in Spain).

B. Operational marketing plan

The company will create a website in which the products and services that will be provided by HyRenCon will be described, as well as the email addresses of each of the members of the promoting team to solve any doubt or request. As it is an innovative product, the controller will be shown in international congresses and industry-specific fairs such as the

World Hydrogen Energy Congress (where the theoretical algorithm was presented in 2016) or in national congresses with the support of AeH2 (Spain's Hydrogen Association).
Most of the possible customers are companies/technological centers/research institutions, so the whole marketing strategy (website, demo videos, portfolio, etc) will be developed in English.

C. HyRenCon description

HyRenCon is a company that designs advanced controllers to be installed in a PLC to optimize the connections and disconnections of a hydrogen-based microgrid. These components are specified in Figure 5.

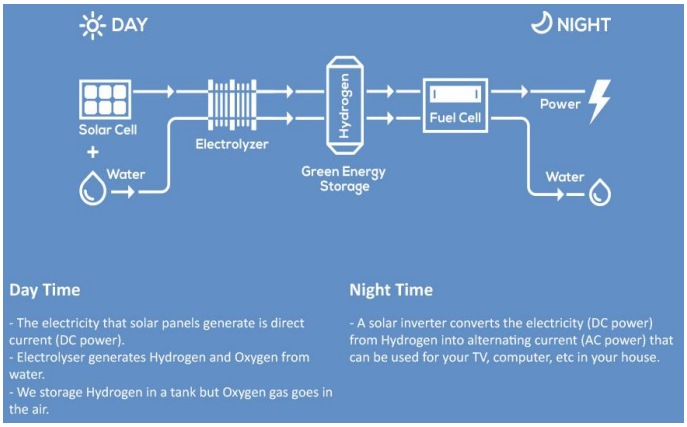

Fig 5. Scheme of a hydrogen-based microgrid for the case of the Phi Suea House in Thailand

(http://www.phisueahouse.com/technology.php)

The energy which supplies the house comes from renewable sources (sun, water, wind...). This energy is used to split the atoms of water (hydrogen and oxygen). Hydrogen has a high calorific value, so it can be stored in liquid form at high pressure. When energy is required in the house (e.g. for cooking, heating the water, turning on the lights, etc), this hydrogen will be used by a hydrogen cell which provides clean energy as it does not emit greenhouse gases (the only residue it emits is water).

HyRenCon would sell the controller of this type of microgrid; more specifically, it regulates the connections and disconnections of the electrolyzer and the fuel cell that provides electricity to the house. The value proposition is based on a control algorithm that uses meteorological predictions. This algorithm manages the operation of the microgrid (when renewable energy is available, the components of the microgrid will be connected in advance). This means that the controller can extend the life of the microgrid components by up to 30%.

The control algorithm would be programmed in industrial PLCs. The cables that link the PLC controller to the microgrid would also be supplied. A PLC has been chosen as the controller as it is the most common industrial controller and because it is easy to adapt and to program in any system.

The use of hydrogen-based microgrids produces benefits for the environment as they do not emit greenhouse gases and they are fully compatible with the environment, so their implementation is ideal in certain locations such as houses in the mountains, on or near the coast, as the installation of the connection to the electricity grid is not necessary.
Nowadays, there is no competitor company that could develop an advanced controller system for hydrogen-based microgrids as HyRenCon does.

Figure 6 shows a hydrogen-based microgrid for the real case of the Phi Suea House located in Thailand. On the left of the figure is the section that generates/consumes hydrogen (hydrogen power system). The PLC would be connected to these devices and it would control the performance of the system. There are also hydrogen tanks which store hydrogen to use in the fuel cell. The system has auxiliary batteries for certain cases in which renewable energy supplies an insufficient amount of energy. Energy sources can be different (e.g. photovoltaic panels, small wind turbines, hydraulic turbines, etc.). These types of microgrid have the great advantage that they do not need to be connected to the electrical network.

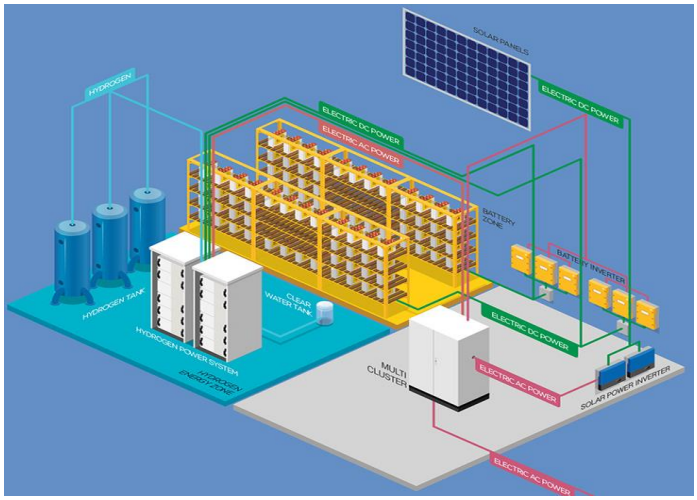

Fig 6. Scheme of the components of the hydrogen-based microgrid.

(http://www.phisueahouse.com/technology.php)

D. Manufacturing

As HyRenCon produces an exclusive product, for the early years until the hydrogen economy becomes more popular, the controllers will be manufactured in a "handmade" way. That is, the PLCs will be programmed one by one, taking into account the special conditions of each client (what type of renewable energy will be used, size and capacity of the house, required power, etc.). The PLCs will be purchased from a company supplier (Siemens, Rockwell, Yokogawa, Honeywell…). Then it will be programmed and the cables will be attached so that the customer can connect the PLC to the microgrid. The PLC will be packaged and shipped via courier.

VI. Financial Planning

In this section, the financial planning for HyRenCon has been estimated for the first 5 years of the company's existence using € as currency. The complete study of the business plan has been developed in the thesis of the author [18], therefore in this paper is presented here a summary of this. The average VAT (Value-Added Tax) rate of 21% has been chosen, as well as 30 days of collection and payment. In the fifth year, a purchase of land will be made to build a small industrial warehouse. An investment for machinery and transport from the second year on will be made, as in that year sales of the PLC controllers will begin to take place. A rental car will also be used. During the first year there will be an expense to create the final patent. There will also be investments each year in computer applications because the company will need computers, printers, electronic wiring, etc.

It is considered that the controllers start selling in the second year. The price of each unit will be 1,000 €, so it is estimated that 7 units are sold the second year, 25 units the third, 50 units the fourth and 95 units the fifth year. Purchases and expenses basically consist of the PLCs and cable purchases. It has been considered that over the years the price per unit of each PLC will decrease, as they would be purchased wholesale. There would be shipping costs, which would be proportional to the PLC purchases.

There would also be bank charges as well as marketing and start-up expenses. These expenses are associated with the registration of fairs, printing of brochures, maintenance of the web, etc. Gains and losses over 5 years are shown in Figure 7.

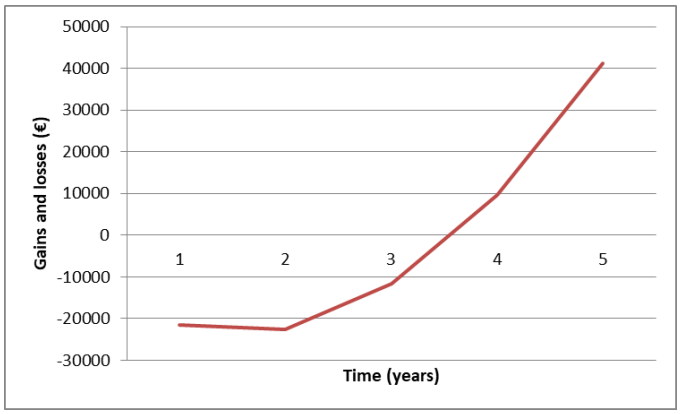

Fig 7. Predictive gains and losses over the first 5 years of the proposed company

It can be seen that, from the third year, the company starts producing profits. This makes sense as the hydrogen economy will become more common over the years and therefore final users would install hydrogen-based microgrids in their houses.

VII. Conclusions

In this work an economic study for a marketable self-supplied hydrogen-based microgrid powered by renewable energies has been detailed. The main conclusions of this study are the following:

- The study of the market of this type of microgrids gives a great potential for implementation in autonomous isolated houses as different renewable can be integrated with the microgrid.
- The Business Model Canvas developed in the annex depicts in a visual manner the most important ideas which should be considered before creating a company (the value proposal, customers, financing and infrastructure).
- The marketing plan of the proposed company HyRenCon shows the internal analysis of the company with the drawbacks that must be overcome before starting to manufacture the product.
- The business plan shows monetary gains from the third year of the company's creation, so it can be considered as profitable.

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