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ENVIRONMENTAL, FINANCIAL AND ENERGY FEASIBILITY OF THE ELECTROLYSIS OF THE WATER STEAM OF A GENERATION IV REACTOR COOLING SYSTEM DURING THE MOMENTS OF LOW CONSUMPTION OF ELECTRICAL ENERGY: CHALLENGES AND PERSPECTIVES

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ABSTRACT

Our civilization is in an inflection moment. Our current decisions will lead us to drastic changes in the planet climate or to cleaner and more sustainable energy generation models. In a certain moment in the evolution of our society, we have privileged the productivity instead of the reasonable use of the planet's resources. This option has been leading us to a situation in which these resources are seriously jeopardized. New models of energy generation and use should be discussed and adopted in order to reverse this process. The electric-power consumption is not constant through time and it must be generated at the moment it is going to be used. There are moments of great idleness in the electric-power generation system, counterbalanced by high demand moments. This characteristic has induced us to the construction of a model of great generation capacity that remains without use most of the time, producing huge financial and environmental impacts. In this article, we discuss the environmental, financial and energy viability of using the idle capacity of the electric-power system to, through water steam electrolysis, produce hydrogen, which would be reconverted into electric power in peak moments by a fuel cell. In this study, we aim at investigating the viability of associating a SOFC (Solid Oxide Fuel Cell), acting as an electrolysis bow, to a generation IV reactor, in order to produce hydrogen from superheated water steam in the cooling of the reactor, which will be converted into electric power via SOFC (Solid Oxide Fuel Cell) in peak moments. The method used in this investigation was to study the electric charge variation consumed in a day, randomly selected in relation to the hour of the day, to launch a curve into a diagram 'Demand x hour of the day', to establish the peak moments, the minimum moments, and the average consumption, and, based on these data and geometrically, predict the viability of using the energetic potential of the moments in which the curve is below the average straight line to compensate the system in the moments in which the curve is above the average, putting it closer to a certain baseline. With these data, we aim at finding out in which level the baseline will stabilize when the energetic losses resulting from the conversions are integrated to the study. As partial conclusion, we have observed that this option would be viable in a universe in which the Second Law of Thermodynamics would not be valid. The never ending of the conversions between energies took the baseline line very close to the maximum point of the original curve, making its adoption, in the energetic point of view, not viable. However, the hydrogen is an input of greater added value than the electric power. As conclusion, we have observed that the technology of using the Solid Oxide Fuel Cell (SOFC), operating as an electrolysis bow associated to a nuclear reactor, shows itself as promising to the production of this important energetic vector that can be addressed to other movable or portable applications.

1. INTRODUCTION

By definition, energy is the 'innate potential to execute work or perform an action'; it is a predisposition to work. If the Industrial Revolution was the replacement of the muscle energy for the mechanic energy, converted from exhaustible sources that harm the environment, it is the moment to use our mind energy to reduce the dependence of ecologically unsustainable energy sources.

Our civilization has privileged productivity, especially of energetic input, instead of the reasonable and sustainable use of the natural resources. ‘The population grows in geometric progression and food in arithmetic progression’, claimed Thomas Malthus in the beginning of 19th Century. This premonition of the end of time could not foresee the field mechanization, the chemical fertilizers or the agricultural chemicals. If, there is famine nowadays, it is not because of shortage of food. However, in the limit, this view is correct. The Earth is finite as well as its resources. The increase of population is pressing the civilization borders to unexplored areas. Ethically speaking, this article will not give support to sustainable solutions by this philosopher or by some 'ecomalthusiasts'. We intend to propose and discuss how to use the natural resources in a sustainable and environmental friendly way.

There is a peculiarity in the ways energy is presented, as for instance, the so-called ‘solar energy’. It is not available at the moment, in the amount and (or) place it is needed. In fact, engineering, environmental and economic problems related to energy is in its logistic - storage, transport and distribution.

There are technologies more efficient to convert, transport and convert back some forms of energy in the places they are needed, namely, the electric energy and the chemical energy - specially the energy found in fossil fuel.

Within this scenery, the emphasis of this article will focus on the generation of electric energy and in how to use system idleness in the moments of low production to, through water steam electrolysis, overheated in IV generation nuclear generators, convert it into chemical energy in the form of hydrogen in a SOEC (Solid Oxide Electrolysis Cell) bow that would be stored and converted back in a battery with SOFC (Solid Oxide Fuel Cell) fuel at peak moments of consume. The strategy used in this article was: 1) to survey the state-of-the-art bibliography of the ‘interesting technologies’ gathering ‘interesting data’, including their electric efficiency; 2) select the ‘interesting moments, which are secondary data, published by the *ONS - Operador Nacional do Sistema Elétrico* (Brazilian Electricity System Operator) [1], in relation to the electric consume registered hourly in a typical workday; and, 3) based on theoretical concepts, develop these data and determine, geometrically, the economic, energetic and environmental viability of converting the electric energy available in the low demand moments into chemical energy and convert it back into electric energy in the consuming peak moments. It is not the intention of this study to exhaust the subject nor to finish this discussion. The article aims at being the proof of a concept and orientation for future decision-making moments.

2. THE ELETRIC NERGY

The so-called ‘electric energy’ is an energetic vector based on the generation of the electric potential difference between two poles, connected by a conductor, which allows to establish a stream of electrons between both. This form of energy is one of the most used nowadays. Within this article purpose, electric energy main strengths are: the relative easiness of its transmission and the low losses of conversion. Its main weakness is the fact that it cannot be stored. In fact, it is generated in the moment it is needed. This characteristic compels its generation centers to be dimensioned to answer to peak consuming moments, what generates uncountable problems, varying from economic aspects to environmental ones, and make them idle in other moments.

In Brazil, the installed hydro-electric capacity is of 70,000 megawatts with potential to reach 260,000 megawatts [2], not taking into consideration the huge impact that the water reservoir, the dam construction, the power station, the transmission lines among other items produce on the environment. These numbers are impressive since they put Brazil among a few countries whose demand for electric energy is supplied specially by hydro-electricity and a fraction of its potential may answer to the demand projections of electric energy for the next years. However, they are not so comfortable as they appear. Great part of this potential is in regions far from the power consumption centers, regions still unexplored. The Instituto Brasileiro de Geografia e Estatística -IBGE- (Brazilian Institute of Geography and Statistics) projects for the next decades that Brazil's population will surpass 215 million inhabitants, with life-expectancy over 80. Indicators of economic activity and life standards [4] show the possibility that we are approaching the limit of exploration of this energy resource.

The document 'definitions and glossary', published by the *ONC - Operador Nacional do Sistema Elétrico* (National Operator of the Electric System) [5], define 'top time' as: 'the period (…) composed by the three daily consecutive hours in which occurs the maximum demand of the day (…)'. This period, in other publications, is also treated as 'peak time'.

Figure 1 presents some data shown in a roughly way. In 63% of the time, electric energy supply for the Southeast/Center-West Subsystem region operates above the average demand and that the minimum demand is 59% of the daily maximum demand. It also shows that the peak time occurs between 6 and 9 pm and that there is a 7-hour period with proportional 'stability' of charge (level) that comes before the beginning of the 'peak time'. This level is 90% of the maximum daily demand.

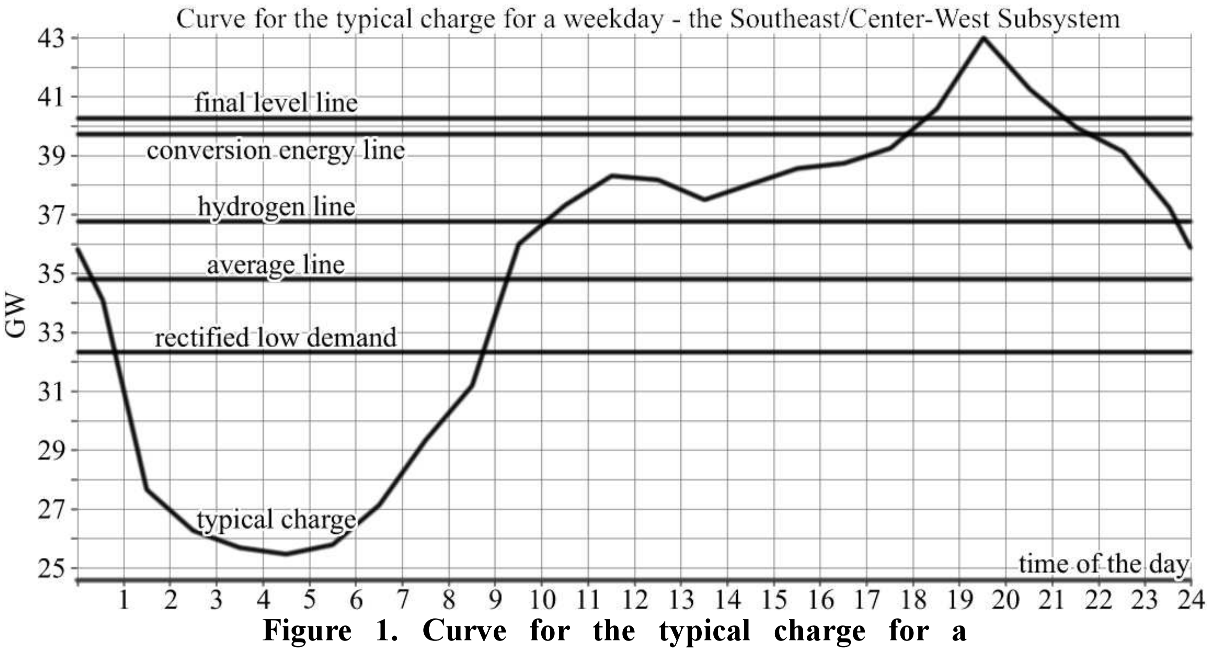

Figure 1. Curve for the typical charge for a weekday - the Southeast/Center-West Subsystem with rectifications

3. TECHNOLOGIES INVOLVED

As it was presented in the introduction, this article aims at analyzing the viability of converting electric energy potentially available in low consuming moments into chemical energy and converting it back to provide energy in the peak consuming moments. There are many technologies available and being developed which lead to this objective. This study identified great potential in the following technologies.

3.1 Generation IV Reactor

The so-called Generation IV Reactor is a set of protocols and concepts being developed aiming at producing, before 2030, a commercial reactor that improves the safe production of electric energy, minimizing the losses and the use of natural resources and whose construction and maintenance would be of low cost.

Within the aim of this stuffy, the main characteristic of this technology is that the reactors will operate at extremely high temperatures (around 1000ºC) and there will be great surplus of thermal energy coming from its refrigeration cycle. Transformed into the form of overheated water steam, it will function as energetic input and raw material in the hot electrolysis process.

3.2 High Temperature Water Electrolysis

The water electrolysis is an electro-chemical process characterized by the happening of oxireduction reactions of a conducting solution in the presence of electric potential difference between two electrodes sunk into this solution. It is a non-spontaneous process, that, theoretically, needs 285.8kJ of energy [6] -enthalpy of water formation-, not considering the losses to dissociate one mol of liquid water, at 298K and 101.325kPa, in one mol of hydrogen (H_2) and half a mol of oxygen (O_2) in the gas state.

High temperature water electrolysis is characterized by using water in its gas state. The watersteam, overheated by an external source, is supplied to the electrolysis cell in the cathode side where, in the presence of electrons, is decomposed into ions of oxygen and hydrogen molecules -equation (1). The gaseous hydrogen is removed as product and the ions of the oxygen migrate, through the electrolyte, to the anode, where they oxidize and combine themselves into molecular oxygen -equation (2)- that can be removed to the atmosphere or used as input to other processes. Equation (3) indicates the water decomposition into hydrogen and oxygen gases, result of this process [8].

$$H_2O + 2e^- \rightarrow H_2 + O^{2-} \tag{1}$$

$$O^{2-} \rightarrow 1/2O_2 + 2e^- \tag{2}$$

$$H_2O \rightarrow H_2 + 1/2O_2 \tag{3}$$

3.3 Hydrogen Storage

In this study, the hydrogen produced by the electrolysis needs to be stored until the moment of being converted back into electric energy. For a long time hydrogen has been produced for industrial applications, among them, the food and the petrochemical industries. Its low energetic density by unit of volume -it means that a specific volume of hydrogen has less energy than the same volume of other fuels- transforms it into a product whose storage is expensive and difficult [9]. The available processes for this reason are intensive of energy and not practical. There are technologies, in different stages of development, with potential to bypass this problem.

The beta version of March 2005 of the Brazilian Report for the structure of Hydrogen Economy in Brazil presents a series of options to hydrogen storage. It takes into consideration the premises that to minimize the complexity of the energetic system and its consequent financial, energetic and environmental costs, it is necessary to reduce the number of chemical and/or physical transformations, to simplify the operation and to use the existing infrastructure.

Hydrogen storage requires investments of financial, environmental and energetic resources, the selection of the best option should be carefully studied so that there is no loss of a lot of energy in this phase. This work does not have the purpose to suggest the best option nor the amount of the needed investments. It concentrates on the method considered the most appropriate up to the present moment.

3.3.1 Hydrogen compression

The gas-under-pressure storage technology is well developed and consolidated, but at high financial and energetic costs. Nowadays, there are tanks in which high-pressure compressed hydrogen can be stored. This technology continues being developed, motivated by the need to meet automotive specifications. Bossel et al. (2003) present these implications [11].

Gas compression requires a great amount of energy whose work needed can be analyzed as a thermodynamic process. Equation (4) describes the gas compression as an isothermal process. It shows that the needed work is logarithmic with base 10. It means that the work and the energy converted into it minimize exponentially with the pressure increase figure 2 isothermal. This characteristic induces to the selection of higher pressure storage methods.

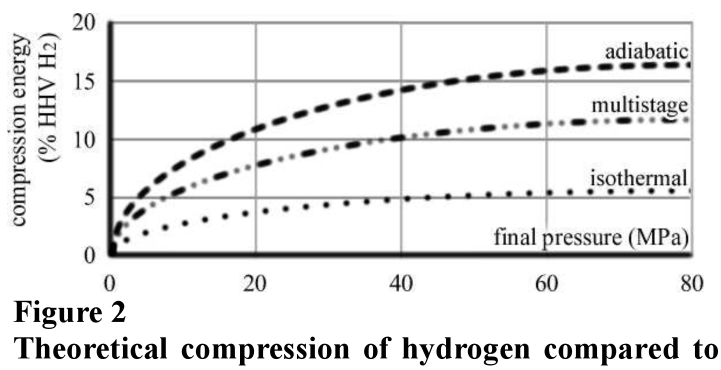

Figure 2
Theoretical compression of hydrogen compared to its higher heating value energy requirements

$$W = p_0 V_0 \ln(p_1 / p_0) \quad (4)$$

However, isothermal compression is not possible in the present state of engineering. When the actuators push the particles of gas, forcing it into the tank, transferring to them part of their mechanical energy, which translates into internal energy of gas. The work done for compression of hydrogen is best described by the equation (5) of adiabatic compression. Figure 2 adiabatic curve.

$$W = [\gamma/(\gamma-1)] p_0 V_0 [(p_1/p_0)^{(\gamma-1)/\gamma} - 1] \quad (5)$$

But, adiabatic processes, by definition, occur without exchange of energy with the outside world. Multistage compressors with intercoolers remove part of the thermal of the system, allowing the work in the compression of gas is somewhere between the work for isothermal compression and adiabatic compression. Figure 2 multistage curve.

3.2.2 Other consolidated methods

There still are other methods to store this energetic vector such as: liquefied, by adsorption in hydrid, compressed in caves, aquiferous, mines or petroleum ores, among other geological formations of the present context. Within this article, these technologies have some weaknesses and will not be discussed.

3.3.3 Other methods being developed

In the condition of ‘the big problem to be solved’, the hydrogen storage, as energetic vector in embarked applications, attracts uncountable minds and resources. There are many methods, in different stages of development, with enthusiastic potentials. Adsorption in carbon nanotubes, retention in glass microspheres, among others have been calling the attention of the community because of the volumetric density of retained hydrogen, at environment pressure, to be potentially close to its liquid state.

In this work, these technologies have the advantage of requiring thermal energy in great amount in the scenery of a nuclear power station, to bring back the hydrogen to its gaseous state and, by the fact that, in a stationary application, the weight of the substrate that will adsorpt the hydrogen is not a problem.

3.4 SOFC - Solid Oxide Fuel Cell

The same apparatus used initially for the overheated water steam electrolysis can be used to convert chemical energy of the hydrogen connection into electric energy, thermal energy and water, reducing, in this layout, the financial and environmental impacts.

The solid oxide fuel cells are the device that more efficiently convert the hydrogen chemical energy into electrical energy. Its working principle is simple. A ceramic electrolyte permeable to oxygen ions serve as separation to the electrodes and, in the present content, to the hydrogen and oxygen gases. The molecular hydrogen is oxidized -equation (6)- when it gets in touch with the electrolyte and with the anode, giving away its electrons that migrate to the cathode through and external circuit, generating an electric current. On the cathode side, it is provided a gas rich in molecular oxygen -atmospheric air, for example- which is reduced in the presence of the electrons -equation (7). The oxygen ion migrates through the electrolyte that, in the anode, reacts with the hydrogen ions, forming water in an exothermal reaction. This process has been described in equation (8) [13].

$$H_2 \rightarrow 2H^+ + 2e^- \tag{6}$$

$$1/2O_2 + 2e^- \rightarrow O^{2-} \tag{7}$$

$$2H^+ + O^{2-} \rightarrow H_2O \tag{8}$$

4. STUDY OF THE ENERGETIC LOSSES DURING CONVERSIONS

As shown before, this study aims to analyze the energetic and ecological viability of using the idleness of the electric low demand moments to produce the energetic vector hydrogen and to convert it back during peak moments. However, there are energetic costs involved that cannot be neglected.

The approach of this research is to select, aleatorically, the 'interesting moments', that are the values of the charge hourly registered on a weekday of any Brazilian subsystem, to plot these data in an diagram of the relation between the 'demanded charge', on the vertical axis, and the 'time of the day', on the horizontal axis, and to calculate the average curve. We start from the principle that the dots of the typical curve under the average line, potentially, could provide the electric energy (converted into chemical energy, stored and converted back into electric energy) to meet the demand of the dots above the average. The adoption of this measure has the potential of replacing the construction of many hydro/thermal electric power stations, diminishing the environmental and financial costs associated to this paradigm.

Starting from what has been plotted in this system of coordinates, we add, to the average curve, the energetic costs associated to the entropic losses of each transformation/operation and, graphically, evaluate the results.

To keep precision, in this study we used the data considered 'tipical' by the *ONS - Operador Nacional do Sistema Elétrico* (Brazilian Electricity System Operator) [1] in its Annual Report of Consolidation of the Charge Prevision -Planning of the electric operation in the medium term- PEL 2009-2010 s.d., to the Southeast/Center-West Subsystem on workdays of May 2009 [14]. These data have been selected because they are not in the daylight saving time. This measure was necessary because, in the peak time of the curve considered typical, the characteristic curve of the daylight saving time shows, practically, reflexive asymmetry to it.

This study will evaluate the energetic losses associated to each phase presented in this process.

4.1 Generation IV Reactors

The energetic losses associated to the conversion chain of the nuclear energy to the electric one, although important, were not considered in this study, since it considers electric energy as input/ primary product of the process above shown.

4.2 High Temperature Water Electrolysis

The water electrolysis is a non-spontaneous reaction. It means that it is necessary that an external source provides energy for it to occur. Under ideal conditions, it is necessary that we provide energy equivalent to the enthalpy of water formation, that is 25ºC and 1atm, 285.8kJ/mol [6]. In fact, this quantity of energy does not need to be provided in the form of electric energy. Part of it can be provided in the form of thermal energy [7], reused from some external process. The equation (9) the portion ΔG is the provided electric energy and the portion ΔS is the thermal energy.

$$\Delta H = \Delta G + T\Delta S \tag{9}$$

In fact, the thermal energy provided is the product of entropy change multiplied by the reaction temperature -figure (3) illustrates the proportion between the electric and thermal energies needed to the electrolysis of a mol of water in function of temperature. It demonstrates that the increase of the reaction internal energy reduce the quantity of electric energy needed for it to happen.

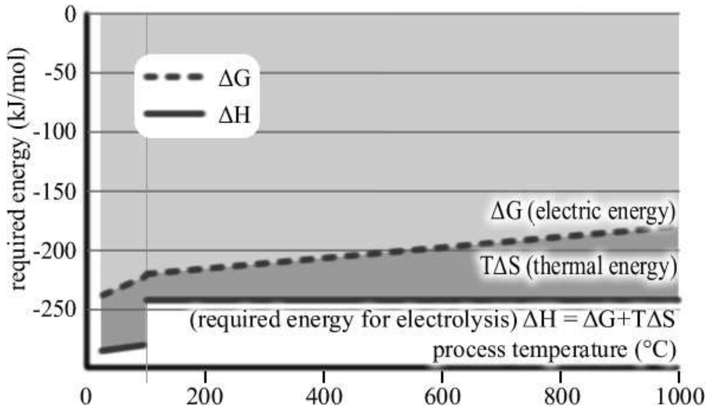

Figure 3
Theoretical electrolysis energy requirements

Nevertheless, part of the electric energy provided for the electrolysis is lost, converted to other forms of undesirable energy. Shin et al. (2007) estimates the global efficiency around 48% for the hot water electrolysis, at the temperature of 1000ºC. As comparison, this presumed global efficiency is twice superior to the efficiency of the alkaline electrolysis of the liquid water (27%) [15].

However, the focus of this study is the utilization of the available electric potential; consequently, it will concentrate in the electric efficiency of the hot electrolysis process. Relating the electric efficiency presented in figure 3 at 1000ºC to the global efficiency of the electrolysis at the same temperature, it will adopt the electric efficiency of 77% for the purpose of the analysis. It means that to produce a mass of hydrogen with chemical energy equivalent to the energetic need during the peak time, it is necessary to invest the equivalent to 160% of this amount into electric energy. But, it is not all.

For a technical idiosyncrasy, the energy that supplies the electric network is generated in alternate current (AC), while the one the electrolyzer uses is in direct current (DC). Bossel et al. (2003) claims that the efficiency of the alternate current converser to direct current increases proportionally to the charge [11]. For the analysis, we will adopt the maximum efficiency pointed out by this author that is 96%. In this way, to produce hydrogen is necessary to invest the equivalent of 167% of its higher heating value in electric energy in this phase of the process.

4.3 Hydrogen storage

Another moment of great use of energy is the hydrogen storage. There are ongoing studies that promise to store the hydrogen, at considerable densities, without being necessary massive investment of energy. However, as it is still being developed, the present study will concentrate on its compression.

4.3.1 Hydrogen Compression

As this study presented before, the energetic investment decreases in base 10 with the pressure increase. It means that, theoretically, it is necessary to invest the double of the energy to compress some gas at pressures ten times higher. To transport the embarked hydrogen -automotive- there are tanks with capacity to store this vector at pressures higher than 70MPa [9]. Theoretically, the density of the compressed hydrogen at 85MPa is near to it in the liquid state.

The storage in geological formations presents financial and ecological advantages, for it makes use of pre-existing structures. Nevertheless, in the energetic efficiency point of view, it is similar to compression storage, inheriting the characteristics of this modality. For prevision effect, this study will take into account the energetic losses to store the compressed hydrogen at 80MPa pressure, in 12% of its higher heating value, since data related to: 1) compressibility characteristic of this gas; 2) the efficiency of the work done in the thermodynamic process, that is associated with the compression system implemented; and, 3) the mechanical resistance to pressure of the selected storage system, only allow us, by now, to infer a single value.

4.3.2 Liquefied Hydrogen

Theoretically, 28.42kJ are needed, less than 10% of its higher heating value, to liquefy one moll of hydrogen; however, the electric, mechanical, thermal losses of this process, among others, multiply the energetic need by factor four. Bossel et al. (2003) [11] present in their studies that the energetic need to liquefy the hydrogen is inversely proportional to the capacity of the power station. For instance: for power stations with capacity inferior to 5kg/hour, the energetic need is superior to 100% of the higher heating value of the hydrogen. More accurate calculations of the energetic efficiency of the hydrogen liquefaction for the scope of this study would not make sense; this way, it will use the value concluded by Bossel at al. (2003) [11], taking into consideration the current stage of liquefying technology of gases, that it is necessary to invest the equivalent to 40% of the energetic content of the hydrogen to liquefy it. To this value, we should add the loss estimate of 3% [11] per day in hydrogen mass that will vaporize because of thermal exchange with the environment, as a consequence of the inefficiency of the thermal isolation of the recipient, totalizing 43% of loss in this phase.

4.3.3 Hydrogen adsorption

The energy needed to store the adsorpted hydrogen varies according to the compost. Bossel at al. (2003) [11] estimate the it is necessary, to this purpose, energy equivalent to compress the hydrogen at a pressure of 3MPa, estimated in 3%, that is considerably inferior than the one needed to store at 80MPa.

For prudence reasons, this study will adopt the pressure storage since it is more consolidated and because its losses are inferior to those in the liquefied storage. Evidently, the modalities of storage by adsorption show great potential and it is reasonable that they are considered in deeper studies. These studies have not estimated the energetic losses with the hydrogen transport among the phases of the process for understanding the values could be dramatically altered in the function of the layout of the installations.

4.4 SOFC: Generation Electric Energy

The final step of this study is to analyze the energetic costs of converting chemical energy, stored in the form of hydrogen, into electrical energy to supply the demand peak time and to reduce, this way, the need to flood environmental reserve areas or arable land to form new reservoirs.

This study adopted the SOFC fuel batteries for a series of characteristics that make them unique. One of them is the fact that these cells operate in high temperatures, between 600 and 1000ºC [13]. This characteristic induces that, for its construction, materials compatible to the temperature level needed to the hot water electrolysis should be used, allowing that the same equipment is used in two different phases of the process, producing considerable financial and environmental impacts. Another characteristic is related to the use of the thermal energy which comes from the ohmic losses during the process and that, in the scenery of a thermonuclear power station, there is available thermal energy for its preheating. There are other characteristics that will not be addressed here because it is not in the scope of this study.

However, this article takes into account that the most important characteristic of this technology is its electric efficiency. Singal et al. (2004) affirm that the energetic efficiency of this technology is directly proportional to the charge and can reach values superior to 60% [13]. It is evident that the global potency can be higher than this value, since there is a great quantity of resulting thermal energy. This article, for its analysis, will adopt the efficiency of 60%, because it considers to 'give back' to the system part of the thermal energy used in the hot electrolysis that was not considered by these studies.

Considering this analysis, this study will take into account that it is necessary to produce, in hydrogen mass, a quantity of 67% superior than that initially expected, and that in the conversion of the electric energy from direct current (DC) into alternate current (AC), in order to be make available to the network, there will be energetic costs of 4%.

4.5 Discussion

The analysis will make use of a 'bottom-up' approach of the proposed question. In figure 1, the area delimited by the average line above and by the typical curve below is equal to the area delimited by the typical curve above and the average line below. In this way, if it were possible 'to store directly', the energetic potential would be enough to meet the needs of the period with high demand. This study investigated the possibility to convert this energetic potential into hydrogen and to convert it back. However, the losses due to the never ending transformations 'push' the resultant line near the maximum charge.

Starting with the principle that to convert the chemical energy of the hydrogen into the electric energy needed during the high demand moments -and, the losses to convert into alternate current and synchronize its pulse with the distribution network- it is necessary to have 74% more of this input (hydrogen line - figure 1), that would be obtained by investing electric energy in an quantity 67% higher than the chemical energy in it -with conversion to direct current- (energy to conversions line - figure 1). The equivalent, in electric energy, to other 12% of chemical energy of this mass of hydrogen would be used by the work of compressing and storing it (final level line - figure 1). What seemed an interesting solution showed up as a waste of energetic resources whose conversion motivated this study -figure 1.

5. CONCLUSIONS

'–In this house, we obey the laws of thermodynamics!'

(Fictional character Homer J. Simpson censuring Lisa, his oldest daughter, for inventing the motocontinuous)

In a universe in which the Second Law of Thermodynamics would not work, this would be a valid option to solve the problems that this study tried to investigate. However, the entropic losses in terms of energy where too high and, in an adverse effect, the generation system of hydroelectricity worked in a potency close to the maximum point during the whole day, a waste of resources that this study aimed to avoid. Evidently, there is theoretical margin to reduce the losses, what should be faced as a challenge.

As final considerations, there are some aspects that seem to be advisable to be considered in future studies of the same kind and that this study was not able to achieve. For instance: the fundamental variable that should be considered is the water mechanical energy that escapes from the system by the spillway and not the idleness of the hydroelectric energy generator apparatus, since, in moments of low pluviometric indexes, the water remains stored in the dam in the form of potential energy. Another aspect that should be taken notice in name of accuracy is that the geometric model approached in this study, although its simplicity and visibility, did not consider the area reduction of the curve above of the new levels of the so-called 'average line', producing, storing and converting back the mass of hydrogen necessary to meet an energetic need that did not exist any longer, using to this, energetic input partially directed to meet the demand. Also, one should observe that the energetic need of the ‘peak time’ could be supplied by the strategy approached in the present study; however, the characteristic of the typical curve of consume, that behaves, practically, as a level of charge very close to the ‘peak time’, led this study to consider that, mantained the consuming distribution along the time, the gain is irrelevant.

Finally, this study elicited the energetic efficiency for the production of the so-called ‘green hydrogen’, in non-corrosive conditions, by overheated water steam electrolysis in generation IV nuclear generators. The hydrogen is an input whose added value is greater than its correspondent in electric energy. Considering the perspective of the current economic context, it does not make sense to use this valuable input in the generation of electric energy in stationary units -except in emergencies, since it can potentially be the energetic vector of innumerous portable and movable applications; moreover, it is a ‘commodity’.

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