DINAMIC SYMMETRY TURBINES

INVESTORS REPORT

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1. Executive Summary

This document intends to provide prominent information to evaluate the possibilities of investment in a new technology-based business project. The objective of the project is to industrially exploit a novel design strategy applicable to gas turbines called dynamic symmetry and with potential to provide a qualitative leap in the benefits of this type of machines. In spite of being conceptually simple, it is a technique which application generates architectures with atypical geometries that depart significantly from the conventional paradigm of design and manufacture of gas turbines so that its comprehension and acceptance may not be immediate. The strategy of the dynamic symmetry is oriented to the design of gas turbines in its broadest sense not being restricted to a specific field of application. This new designing philosophy has a direct impact on physical aspects such as the working temperature of the materials, heat recovery, the distribution of structural stresses or the weight. However, that does not mean that a certain increment in efficiency or a certain reduction in weight could be linked to the mere fact of applying the criterion of dynamic symmetry. Quantifying these advantages will depend entirely on the development process of the particular product. For this reason, the start-up phase of the project will have as objective the generation of one or more designs in order to demonstrate the degree of real improvement achievable through a work of quality engineering. The success of this phase will be to determine the value and acceptance of this technology in the target market.

Gas turbines are machines that convert thermal energy of a fuel into mechanical energy. They are used in the generation of electrical energy and as an engine to drive industries or vehicles of all kinds. Forecasts of energy demand and the favourable expectations in the technical improvement of the turbines foretell a promising future for this technology in the coming decades. An emerging market and with high potential for growth is the one of the very small power gas turbines or micro-gas turbines. Either generating distributed electrical energy or powering small sized vehicles, the characteristics of this market and of the own micro-gas turbines make it a preferred target to test the innovation because it is expectable that thanks to it they can operate in more extreme conditions increasing their efficiency and benefit from other improvements. The chosen business model will have as main activity the commercialization of exploitation licenses for this technology, currently patent pending, and become a benchmark of R&D on the same. The initial investment that is described in this report is the required to execute the start-up phase whose mission is to demonstrate through research the benefits achievable when applying the criteria of dynamic symmetry. Having identified the market of micro-gas turbines as a priority, and with the objective of minimizing the economic risk, it was decided to plan an initial research consisting in the design of micro-gas turbines technically feasible in the short-term and commercially disruptive. If there is success in the start-up phase a continuation phase will be subsequently attacked in which a more definitive infrastructure to the business activity would be adopted.

Regardless of how different aspects of the project are labelled, the only information undoubtedly objective is the actual description of the technology and the fact that there is an international patent record that is progressing well. Some evolution expectations of the market or a financial projection in

the exploitation of the innovation itself would not be more than opinions, estimates or extrapolations of questionable validity and accuracy and subject to interpretation. Therefore the information provided in the document is not focused to establish speculations but is basically geared to form a clear perception of the usefulness of the new technology. This report is addressed to people and to private or public entities interested in investing in technology-based projects potentially relevant to the energy production, propulsion and defence markets. The considered hypotheses are not immovable at all and the proposed business model does not constitute the only admissible formula to lead the exploitation of this technology. It is only an alternative to assess, but that does not exclude other investment or collaboration options. To evaluate this report it is convenient to have a basic knowledge on engineering and gas turbines industry. From a scientific and technological point of view it does not require a degree of scholarly understanding of thermodynamics, fluid dynamics, chemistry, metallurgy or structural strength to fully understand this innovation because it affects only the geometry of the rotors without conditioning materials or manufacturing processes.

Warning: It has been found that the simple vision of a dynamic symmetry turbine for the first time can cause an immediate rejection effect that determines any subsequent evaluation. Contrary to what happens with those who have training related to strategic planning, the technical staff does not usually be forewarned of the great influence of certain cognitive defects in the decision-making processes. This can lead to the fact that the preference of the investor by ideas that break with the established collide with the prejudice of the technician that irrationally associates an idea which breaks with the established to a bad idea. Throughout the document resources to try to prevent this problem are provided.

2. Brief history of the project

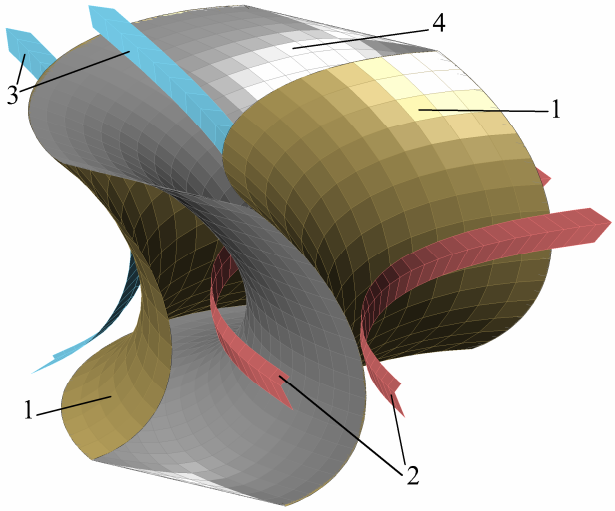
Achieving more efficient, smaller and lighter engines are objectives permanently pursued by the engineering. A great interest exists by progressing in the development of gas turbines as energy conversion technology that is prompted by both private industry and diverse initiatives of the public sector. The research of materials that support better the extreme conditions present in the gas turbines, variations in the refrigeration systems or the exploration of complex thermodynamic cycles are allowing the gradual improvement in the performance of these machines. However, despite the great efforts and resources invested in R&D, these improvements are taking place very slowly and by means of small steps. Even today, the technological cost to manufacture a gas turbine and the energy efficiencies achieved prevent the classic explosion engines to be definitively displaced as a conversion system of thermal energy into mechanical energy. This is most clearly evident upon speaking of small power engines. Traditionally the basic configuration of gas turbine engines has had three functional blocks clearly separated: compressor, combustor and turbine. The turbine is the responsible for supplying the required power to drive the compressor and, in its case, for delivering the useful power to the shaft of the motor. This fact implies that the compressor must be dimensioned to withstand the power of compression and, in the same way, the turbine must be dimensioned to withstand the sum of the power of compression and the useful power in its case. In addition there must be some transmission system which transmits the power of compression from the turbine to the compressor and, obviously, it must be dimensioned to withstand such a power.

Looking in wide perspective at the technological environment of the gas turbines gets itself the impression that the successive innovations that have been occurring in recent times in this field of technique denote a great difficulty to get away from the path marked out by the classical formulae. The basic modular architecture of compressor, combustor and turbine is maintained; concepts remain the same as always in the geometry of the blades and in the cooling schemes; and, finally, increases in performances are only being scratched very little by little to a high economic cost. All these circumstances led me to think that, without a substantive advance in the technology of the materials, the only way to achieve a qualitative leap in the profitable characteristics of the gas turbine motors would pass for changing radically the classical paradigm with which the architectures of these machines are designed. Once accepted this premise it became essential to question the suitability of some rules:

- The configuration of the machine does not have to be modular with the compressor, combustor and turbine separated.
- The fluid trajectories do not need to be two-dimensional or almost two-dimensional. The fluid can describe three-dimensional trajectories since what is really important are the thermodynamic conditions at the beginning and end of such trajectories.
- The surfaces through which the fluid passes do not need to be approximately developable nor respond to two-dimensional extruded profiles. A three-dimensional geometry with irregular warping can also conduct the fluid correctly if it is properly designed.

All the internal combustion engines present some common functional characteristics. The engines take air from the atmosphere, compress it, after being compressed thermal energy is added, and it is finally expanded extracting mechanical energy. The energy delivered by the motor, useful energy, is always smaller than the energy extracted in the expansion phase of the thermodynamic cycle. This is due to the fact that the expansion phase must supply not only the useful energy, but also the energy required for the compression phase. In addition, for the same useful energy, the compression energy will be greater the higher the compression rate of the engine is. In a gas turbine, this really means that the turbine must be dimensioned to withstand the efforts relating to the sum of the useful power and the compression power, that the compressor must be dimensioned to withstand the efforts of the compression power, and there should also be a transmission element between the turbine and the compressor dimensioned to withstand the efforts of the compression power. The question arises then: **Would it be possible to design a gas turbine whose mechanic had to withstand only the useful power?**

Thus began a long process of mental evaluation of ingenious occurrences that concluded with the design of a new architecture for the rotors which, at first glance, showed both positive and negative aspects. It essentially consisted in that the compression and expansion channels were embedded in the same rotor element using a combination of warped foils with double curvature. As positive aspects it was highlighted that all the material on the rotor in contact with hot gases flow from the combustor was also in contact with the cool air flow to compress, that is to say, refrigerated; the configuration was comparable to a rotary heat exchanger allowing to raise their use as heat recoverer; from a structural point of view, the rotor just had to be capable of withstanding the efforts for the useful power because the efforts for the compression were compensated between compression and expansion channels, which translates into a weight saving that joins the absence of a power transmission system between the turbine and the compressor; and from a constructive point of view the entire rotor could be essentially manufactured from two types of elements. The negative aspect was something entirely subjective, but of an important psychological impact due to be originated by the impression that this was a tremendously extravagant solution with all the unfavourable connotations and doubts about the viability of the idea that this entails. That negative first impression corresponds to a bias of rejection to the unknown according to which the strange ideas or far removed from the familiar ideas cause rejection. It is not the only usual cognitive defect to consider, it can also have a decisive influence, and in the opposite direction, the selective perception according to which individual desires and ambitions cause the overvaluation of those factors that enhance positively their interests and the



underestimation of those others that are opposed to those interests. The mechanism to avoid these deviations is relatively simple and consists in withdrawing from subjective appearances to see things as they are free of predispositions. The objective results of the analysis of this new architecture were the following:

- The rotor has compression channels delimited by aerodynamic surfaces, that is to say, there is an operative compressor.
- The rotor has expansion channels delimited by aerodynamic surfaces, that is to say, there is an operative turbine.
- The configuration offers lots of degrees of freedom so that in the designing process, curvatures, orientations, leading and trailing edges, cross-sections, heat transfer areas, etc could be adapted.
- The material of the rotor is simultaneously in contact with the compressing air flow and with the hot gases flow from the combustor so it will be at an intermediate temperature.
- There is no compressor element dimensioned to withstand the compression power, there is no turbine element dimensioned to withstand the expansion power, there is no transmission shaft dimensioned to withstand the compression power. There is a rotor element instead dimensioned to withstand only the difference between the expansion and compression power, that is to say, the useful power.
- The architecture is susceptible of being used as heat recovery system.
- The physical phenomena that govern its operation are exactly the same as in a conventional gas turbine.

After the analysis I could conclude that the innovation was physically viable and there were reasonable expectations to get several interesting advantages compared to conventional designs, although it would be necessary to apply it to real processes of product development in order to be measured. After conducting a search for possible background, on March 30th, 2012 I handed in an international patent application in the Spanish Patent and Trademark Office. On October 16th, 2012 I received the International Search Report of the International Searching Authority with completely favourable outcome. Time had come to try the industrial application of the new technology.

3. Description of the technology

For the understanding of the technology of dynamic symmetry turbines can be preferably used the reading of the popular technology article that is found in Annex 1 to this document or accessible on the Internet through the official website at the URL:

http://www.dsturbines.info.

By the experience accumulated in the dialogue with different experts attention is drawn to the desirability of reading the section called "Warning for bias of rejection to the unknown". Alternatively, it can be used the consultation of the patent application that is found in Annex 2 to this document or accessible on the Internet through the International Patent Office in the URL:

http://patentscope.wipo.int/search/en/WO2012098277.

Once the new design philosophy is understood, the following comments on the matter are made:

Since it is an innovation that affects the design of the rotors geometry its evaluation and management does not require knowledge or different tools to that required to work with conventional gas turbines. In fact, for its comprehension it will be enough to be clear about the principles of its performance not being necessary to be a scholar. Due to the special geometrical characteristics of the dynamic symmetry turbines it is not possible to speak of blades itself as a constructive element. We can talk about the concepts of pressure surface (active), suction surface (passive), and compression and expansion channels.

Besides the more or less complex cooling circuits, the blades of some conventional turbines also employ a system of holes that inject compressed air from the inside to form a protective gas film that coats the surface of the blade protecting it against heat and chemical reactivity of the gases produced by combustion. In the dynamic symmetry turbines refrigeration is achieved in a natural way when circulating the air to be compressed by one of the sides of the foils that compose the rotor. Since the aerodynamic torque corresponding to the expanding gas flow is necessarily bigger than that of the compressing gas flow, it is easy to deduce that the average pressure on the hot side is greater than on the cold side in the dynamic symmetry foils. This being so, dynamic symmetry apparently would not permit, without more, the implementation of the protection mechanism by gaseous film. Although by raising that problem it is also immediate to deduct that when a fluid flow moves at a certain speed respect to the surface on which it circulates it is not difficult to manipulate that surface geometry to dynamically cause local depressions or overpressures as interested. That is to say, it is feasible the generation of a protective air film on the hot side of the foils designing properly the aerodynamics of the holes that would inject that air from the cold to the warm side. This technique will be with difficult to apply just in the leading edges of the expansion channel area. In any case, the dynamic symmetry is compatible with the use of other systems and other current designing techniques.

Since the physical phenomena involved in the operation of a dynamic symmetry turbine are the same as in a conventional gas turbine, it would turn out to be repetitive and impractical attaching the same theoretical formulation that could be found in any detailed study upon thermodynamic calculation of gas turbines. What is certain is that the thermodynamic cycle in the dynamic symmetry, when using the heat recovery is wanted, is not easily comparable to other existing thermodynamic cycles. The heat exchange occurs within the compression and expansion channels, not before or after, and that implies punctual uncertain thermodynamic conditions until the final definition of the geometry and operating parameters. Of course, it is perfectly feasible to establish hypotheses for modelling this heat transfer in particular cases and obtaining estimative formulae useful as a starting point. Anyway, a preliminary design resulting from theoretical formulae should be evaluated and optimized by simulation before materializing it in a prototype. When designing a real application it cannot be forgotten the possible convenience of, as the case may be, minimizing or maximizing the heat transfer effect in the rotor, or combining the dynamic symmetry turbine with intermediate coolers in compression, when there are several stages, or with a conventional recoverer with the typical location between the compressor and the turbine outlets, or with a steam cycle, or integrating it into any of the existing standard solutions.

4. State of situation

At the date of preparation of this report:

On March 30th, 2012 it was requested the international patent number PCTES2012000078 with the title "DYNAMIC SIMMETRY TURBINES" and subsequently published with the number WO2012098277. On October 16th, 2012 the International Search Report and the Written Opinion of the International Searching Authority are received with a favourable outcome, which means that it has not been found any background in conflict with the request. The Written Opinion expresses that the claimed invention fulfils the requirements of novelty, inventive step and industrial applicability; it also recommends that the optional features expressed in the only original claim are to be separated in dependent claims. The International Search Report of the International Searching Authority may be found in Annex 3 to this document. After hiring the services of a patent agent, on January 15th, 2013 it is remitted to the International Patent Office the amendment of claims according to the Written Opinion of the International Searching Authority recommendations. All documents published by the International Patent Office related to this application record are accessible on the Internet through its website at URL:

http://patentscope.wipo.int/search/en/WO2012098277.

On March 30th, 2013 expires the one year term for requesting patent with priority out of the PCT convention. On September 30th, 2014 expires the 30 months term to enter the national phase of PCT convention.

The technology has not yet been tested in a technological demonstrator nor has been applied to the design of a technology demonstrator.

The activities relating to this technology are being leading through a physical person, not a company. There have been no requests for trade marks or other distinctive signs. The Internet domain dsturbines.info has been hired as temporary instrument of disclosure, but the term "dsturbines" is not intended to be or to be part of a distinctive sign.

5. Strategic view

5.1. Generalities

In spite of the logic uncertainty associated with projects that require researching and that depend on future situations, the nature of the base technology for this project makes it easy to know what is useful for and to sense which can be the investment needs to develop it and the possible paths to capitalize it. While, in the current actual state, a benefits projection or a probabilistic forecast would be mere speculation, it does not escape any expert attention that gas turbines are a product that exists since long time ago in a global properly-seated market, in a known competitive environment and with clear needs. And of course, the R&D activity that surrounds this project is not at all strange to the gas turbines industry whose business is always moving in a high technology and constant innovation context. It would not be unreasonable to ensure that the project breaks with established, both by the technical solution itself as for have been born from an independent research. But, without trying to detract from the value of the image, the target market is not fashion market, or art market, is not fed from appearances or subjective impressions but from facts. Beyond connotations and prejudices, achieving an industrial application of the dynamic symmetry criterion that will result in a remarkable improvement in efficiency or weight or in constructive simplification would mean a technical and advertising success, not because of that particular case but for the psychological effect to be able to associate the innovation to the idea of measurable advantage rather than to the idea of uncertainty. The dynamic symmetry technology may not be directly sold as a design philosophy that provides an increase X in the efficiency or a reduction X in the weight. The perception of the value and the utility of this innovation will depend on the results obtained during its application. A negligent work with this or with any other innovation, however wonderful it may seem, would ruin the image and the cultivated hopes seriously undermining their future options. Therefore it is essential that the first R&D works performed with it are of the highest quality to demonstrate up to where it can get if appropriate means are provided.

Like any other research project, this also has an initial value, precisely the potential value that those who, after the analysis of the expectations decide that the investing risks of the research are acceptable, wish to assign. Being the starting point the actual one, that is to say, a patent, the formulae of obtaining incomes are essentially three: to sell the patent, to grant exploitation licences to third parties, or to produce and to commercialize gas turbines with this technology starting from scratch. The gas turbines industry is a high-technology industry either in the engineering and designing segment, in the materials one, in the control systems one or in the manufacturing one. Although the advantages of the dynamic symmetry turbines will be demonstrated, the pretension of starting from scratch one of these industries, not being absolutely impossible, might not make economic sense when there are already several entities competing in the market with strong brand, extensive technical experience and a well organized production and marketing infrastructures. Since to exploit this innovation, someone inevitably has to take the initial R&D risk, both the option of selling the patent directly as it is, as demonstrating its advantages and subsequently granting licenses are equally viable. All depends on the way to be committed to it. If finally the option taken is the

manufacture, the most logical option would be a strategic alliance with an already established company able to cope in good conditions with the high demands on engineering, manufacturing and homologation.

Being reasonably clear how to capitalize the technology of dynamic symmetry turbines, information about trends, competitive landscape, strengths, weaknesses, threats and opportunities is outlined hereafter, that may be useful to reduce some of the uncertainty in the task, much more complex and subjective, of quantifying their potential value in the medium and long term.

5.2. Market environment and prospective

The economic expense in the production of electric energy is a growing concern everywhere. A constant increase of the demand, the gradual decrease of fuel natural reserves, the environmental restrictions to the emissions of contaminants and greenhouse effect gases, the reluctances to the use of nuclear energy and other geopolitics nature problems that affect to the security of the supplies contribute to that worry. The renewable energies are a sure value, but its development continues being expensive and its availability is discontinuous so much in the time as in the geography. Forecasts suggest that in the coming decades the fuels will continue being the main sources of energy, between 62% and 75% in 2035 according to the foresight of the International Energy Agency (IEA). The high degree of development reached up to the date on the technology of steam and gas turbines and the high potential for improvement that it still has invite us to think that it will be a preferential technology for the conversion of energy from fuels in the near future. In the field of propulsion, the expectations are equally favourable. The ability to produce high power occupying small spaces, the ease of burning diverse fuels, the proven suitability for air transport and the advances in hybrid propulsion makes it a promising option. It is also necessary to mention the increasing interest in having access to small and medium powered gas turbines with better performance than those in current use, in order to strengthen its implementation in sectors such as the distributed production of energy or the driving of mobile platforms and small vehicles. This interest is extensible to the so-called ultra-micro-turbines, gas turbines of very small size still in experimental phase and from the ones is expected that can be used as power generation portable units, to meet the energy needs of independent residences, drive small military devices, etc.

This optimism is derived from diverse sectoral groupings manifests, presentations of important R&D programs financed with public funds and the most recent annual reports published by the key players in this industry such as General Electric, Siemens, Mitsubishi Heavy Industries, Rolls-Royce or Capstone Turbine in the segment of the micro-turbines. Although it is not useless to qualify it with information that enable to infer some indicators of the need that at the present situation exists for finding notorious innovations in conversion technologies and, in particular, in gas turbines. Include a survey published by Diesel & Gas Turbine Worldwide about orders of large reciprocating engines, gas and steam turbines. Although the representativeness of the data is affected because not all the sectors neither the manufacturers are reflected, it is significant the downward trend of gas turbines orders in the last years in front of the upward trend of the reciprocating engines orders. Another revealing statistic published by the IEA shows the trend between 1973 and 2005 on the influence of

the improvements in energy efficiency and compares it with the trend in the own energy consumption. The countries considered were: Australia, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, United Kingdom and the United States. According to that statistics, without the improvements in energy efficiency achieved between 1973 and 2005 energy consumption would have been a 58% greater. But this statistic yields another interesting result. While in the period 1973-1990 the average rate of growth in energy efficiency was 2% annual, during the period 1990-2005 the rate dropped to 0.8 % annual. At the same time, while during the period 1973-1990 the average rate of growth in energy consumption was 0.5 % annual, during the period 1990-2005 this rate increased to 0.9 % annual. Apparently the savings strategies and technological advances manifest a wear in the capacity to produce new significant improvements, while energy demand increases in an accelerated manner.

One of the big commitments for energy savings up to the day is the cogeneration or CHP (Combined Heat and Power). The strategy of generating electrical energy and simultaneously take advantage of the residual heat from the generator to satisfy the needs of heating constitutes a rational formula to exploit the energy sources with a very high efficiency. To boost this strategy the distributed electric power generation is ideal approaching the source of residual heat to its potential consumers. Apart from the savings, the cogeneration by means of distributed electrical power leads to a more robust energy distribution infrastructure what constitutes one more reason to strongly promote its dissemination from institutions by investing in R&D and regulating markets. According to the Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy the CHP capacity installed in the US in 2006 was 85 GW while it is estimated that it will be of 241 GW in 2030. According to the Strategic Energy Technologies Information System of the European Commission the CHP capacity installed in the EU-27 in 2011 was of 95 GW while it is estimated that it can arrive to 235 GW by 2030 in the adequate conditions. And as indicated by the R&D and promotion of the use of CHP programs, in both the European Union and United States, the turbines and micro-gas turbines occupy a prominent place as key and long-haul technologies for the CHP strategy.

Aside from identifying the potential target markets for the exploitation of the dynamic symmetry turbines, it is equally transcendent to be able to decide where the innovation should be protected. Even knowing the results of researches that allow to check the benefits of the new technology in a reasonably accurate way, the choice of a list of countries in which requesting patent would continue having a high degree of subjectivity. By obviating the fact that the ideal would be always to obtain the exclusivity at global level, if one observes the protection guidelines for large companies that innovate in this field of technology it is verified that it is not common practice to request patent in tens and tens of countries pursuing the universality of the protection. The list of countries where it is used to patenting is relatively restricted and the length of that list of course will depend on the value that is estimated for the innovation. Although in the planning for the protection of intangible it will be probably employed some deterministic formula that, from macroeconomic parameters such as gross domestic product, population, industrial production, economic freedom index, energy consumption, defence budget or others, allows to calculate a priority indicator for each nation, it must be admitted the

existence of an influential circumstance more psychological than mathematical. Gas turbines are products that require high technology, a great specialization, heavy investments in industrial infrastructure and R&D and a considerable engineering effort to achieve a design suitable for launching to the market. Thus, the strategy of patenting only in the main national territories and not in all of them makes sense because that is a notably dissuasive factor for a third party that had the pretension to exploit the innovation in a non protected market in an isolated way, whenever it would be obliged to compete in clearly disadvantageous conditions with those companies that also have access to protected markets, which are also the most important.

In a non-exhaustive search conducted on patents database of the World Intellectual Property Organization (WIPO) it is checked that among the list of countries preferred by the manufacturers of gas turbines are especially the G7 ones, China, South Korea, Australia, Russia and other European countries. More objective is the result of a statistics provided by the WIPO in which is consulted the total number of patents granted by each office between the years 2005 and 2011 relating to engines, pumps and turbines technology group. The table is descending organized by the number of patents and contemplates both countries and aggregated data for continents and regions:

OFFICE	TOTAL
World	138025
Asia	64393
Europe	38981
Japan	38642
North America	30931
United States of America	27999
European Patent Office	15115
China	14489
Republic of Korea	11115
Russian Federation	7394
Germany	6180
France	3882
Canada	2932
Oceania	1662
United Kingdom	1581
Australia	1300
Spain	608
Latin America and the Caribbean	493
Brazil	479
Sweden	456
Poland	410
Ukraine	403
Soviet Union	396
Austria	390
Norway	387
New Zealand	362
Africa	314
Netherlands	288
Eurasian Patent Organization	231
South Africa	199
Czech Republic	193
Romania	191

Switzerland	179
Greece	148
Finland	142
Georgia	79
Slovakia	71
Malaysia	67
Denmark	57
Slovenia	56
Croatia	50
Bulgaria	38
Morocco	38
Portugal	38
Hungary	36
Lithuania	32
African Regional Intellectual Property Organization	28
Egypt	28
African Intellectual Property Organization	21
Cuba	9
Luxembourg	9
Estonia	7
Iceland	6
Nicaragua	4
Latvia	3
Patent Office of the Cooperation Council for the Arab States of the Gulf	3
Republic of Moldova	2
Chile	1
Italy	1
Serbia and Montenegro (formerly Yugoslavia)	1
Tajikistan	1

Although the reading of certain indicators of countries such as Saudi Arabia, Argentina, Iran or Pakistan, that are outside of the Patent Cooperation Treaty (PCT), could invite to consider them as territories to protect, it is true that they are not among the priority destinations in patent applications. Finally, the extension of the innovation protection will be strongly conditioned by the greater or lesser utility that can be shown for the same during its application and will not be invariant over time being able to be abandoned in certain territories depending on the project evolution.

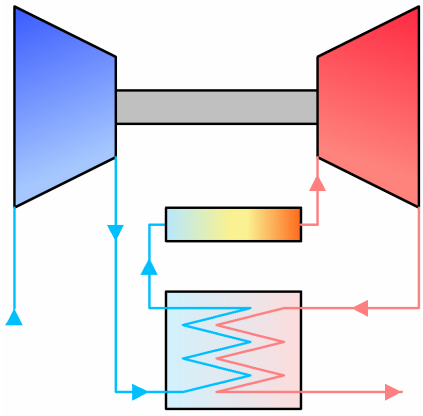
Some of the sources consulted:

- International Energy Agency (http://www.iea.org)
- European Turbine Network (http://www.etn-gasturbine.eu)
- General Electric, annual report (http://www.ge.com/annualreport)
- Siemens, annual report (http://siemens.com/annual-report)
- Mitsubishi Heavy Industries, annual report (http://www.mhi.co.jp/en/finance)
- Rolls-Royce, annual report (http://www.rollsroyce.com/investors)
- Capstone Turbine, annual report (http://www.capstoneturbine.com/investor)
- Diesel & Gas Turbine Worldwide (http://www.dieselgasturbine.com)
- World Alliance for Decentralized Energy (http://www.localpower.org)

- U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Distributed Energy (http://www1.eere.energy.gov/manufacturing/distributedenergy)
- Advanced Microturbine System: Market Assessment (http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/microturbine_market_assess.pdf)
- European Commission, Strategic Energy Technologies, Cogeneration of heat and power (http://setis.ec.europa.eu/technologies/Cogeneration-of-heat)
- COGEN Europe (http://www.cogeneurope.eu)
- California Energy Commission, California Distributed Energy Resources Guide (http://www.energy.ca.gov/distgen)
- OECD Patent Statistics Manual-2009, ISBN: 9789264056442 (http://www.oecd-ilibrary.org/content/book/9789264056442-en)
- World International Property Organization Statistics (http://www.wipo.int/ipstats)
- The Heritage Foundation, Index of economic freedom (http://www.heritage.org/index/)

5.3. Opportunities

The criterion of dynamic symmetry is a designing philosophy applicable to gas turbines in its broadest sense. Determinant factors such as power, the number of stages, the type of fuel or the destination of the machine do not limit its use. A simple construction that provides a good cooling system, an ability to withstand higher structural response thanks to the compensation of compression efforts, and the ability to operate as a heat exchanger are factors that play in its favour. However, it is a new technology in a very early stage of development. The uncertainty and the logical need to limit the risk recommend advancing cautiously and beginning slowly. The large gas turbines are technically very sophisticated, in general they already have cooling systems and they have several compression and expansion stages which complicates their design. The high investment required, and the waiting time to obtain results of the R&D advise against facing this challenge in the start-up phase being better to postpone it to a more advanced stage. There is already a market niche in the industry whose characteristics make it an ideal target to test this innovation. It is the micro-gas turbines market, machines from among 25 and 500 kW of power that reach efficiencies of the 30% (regenerative) and are mostly used in the generation of distributed electrical power and in the driving of industries disconnected from the main network. As it is observed in the figure, they will normally be formed by: compressor, combustor, turbine and heat recoverer. Bearing in mind that this is a relatively new growing market, that the machines operate in static locations, that for that power range are usually employed simple rotors of one or very few compression and expansion stages without cooling system, and that there is a demand for improvement, it can be considered an excellent option to start because they are relatively undemanding applications in development infrastructure and, surely, there would



be a good receptivity to drastic innovations. The developments that are carried out for the micro-gas turbines market are equally valid for the auxiliary power generators or APU whose demands, from a technical point of view, are virtually identical. In the medium term these designs will serve as a basis for the developments designed to satisfy a market with high growth potential, the one of the engines for small power vehicles and to drive mobile platforms.

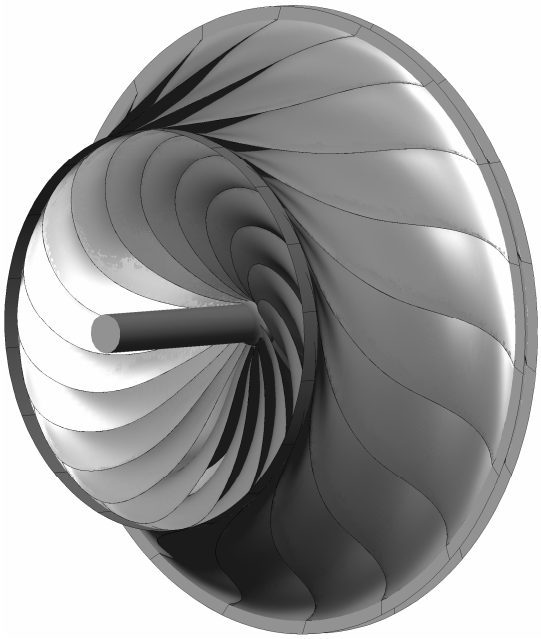
But the range of opportunities offered by the technology of the dynamic symmetry turbines should not be analysed only from a technical perspective of the product. From a strategic perspective, the control on intangible assets represented by the patent can be a very relevant competitive advantage. This innovation in the development phase is in itself an opportunity to invest in R&D for any company interested in enhancing the occupation of those engineering resources that, by the current economic conjuncture or other circumstances, are under-used or simply wasted in researching projects with low profitability expectations. Also, assuming the R&D effort in the start-up phase, is an excellent opportunity to initiate in favourable conditions a new business line based on a novel technology that allows to produce industrial goods clearly differentiated from the competitors. For those entities that operate in the gas turbines industry, with growth potential, but that for historical reasons go behind the technological power of the companies that have traditionally dominated the market, it may mean a very attractive opportunity to be positioned in front of them with an innovation absolutely independent from them. The successful implementation of the dynamic symmetry criterion to the design and manufacture of micro-turbines and ultra micro-gas turbines of high performance could make it a critical technology in the short and medium term for the defence market in countries with ambitious development policies in the field of military robotics.

5.4. Research

After identifying the micro-gas turbines market as a priority objective, the first researches should be aimed at the optimized design of a technological demonstrator that is industrially viable in a short-term and commercially disruptive. This is immediately translated into a need to achieve technical simplicity and clearly advantageous performances regarding to the alternatives present in the market. Looking for a set of requirements that can be considered medium among the current offer of this type of machines it is concluded that a 100 kW micro-gas turbine with recuperative cycle is an adequate option for a first project. As it is shown in the section "Current researches" of the popular technology article, it would be able to opt for designing a scheme in which there would not be an external heat exchanger because such systems are already commercialized and their simplicity is maximum. It is perhaps too pretentious, but it would be a milestone to achieve that a dynamic symmetry rotor without external heat recoverer would provide a higher efficiency than a conventional micro-turbine with recuperative cycle. In spite of it, it has been preferred the recuperative cycle option for tactical reasons since it does not imply an extraordinary complication and its materialization would be commercially more disruptive than the simple cycle one.

The dynamic symmetry will provide the possibility of achieving more extreme operating conditions and the rotor will probably have a lower inertia facilitating its start-up. The fact that the use of an external heat exchanger between the compression channels outlet and the expansion channels

outlet is already foreseen, as it is a recuperative cycle, doesn't mean that we should despise the possibility offered by the rotor of dynamic symmetry foils to also function as heat recoverer and not only as a refrigerator. Once the hot gases reach the exhaust conditions, any heat exchange permits to extract some mechanical energy. However, when such an exchange occurs at an intermediate compression stage, as is this case, it has as consequence an increase of the required compression power and temperature to reach the same final pressure, something not desirable a priori. But one must also keep in mind that the rotor of dynamic symmetry foils incorporates refrigeration and, besides, the compression power does not have the same structural repercussion that in a conventional one thanks to the partial compensation of pressures between the compression and expansion channels. We must always bear in mind the objective of maximizing the compression rate and, taking advantage of the fact that there is heat exchange, look for the minimum exhaust gas temperature. Although the result depends on the entire system, in order to reduce the cost of the first research phase it can be established several simplifying hypotheses which do not undermine significantly the calculations and that severely limit the number of items to assess. The most difficult element to design is the rotor and it is the only directly affected by the criterion of dynamic symmetry. Having said this, the first research phase will be designing an optimized dynamic symmetry foils rotor integrated in a recuperative cycle capable of delivering a 100 kW power to the shaft. It is a well-defined objective, of measurable results and achievable in a limited period of time. This first phase has a crucial importance. The design realized by expert professionals with engineering tools of proven productivity and reliability in the industry will indicate with an acceptable accuracy the sought quantification of the advantages of this technology. In other words, it is the minimum investment necessary to get having objective data to help making the decision of continuing or to abandon. Thus, for example, if the result were favourable it would have arrived the time to choose whether to continue with the complete design and manufacturing of the technological demonstrator, or to officially publish the results and offer licenses to manufacturers, etc.



It should be clear that the result of this first research is the design of a rotor, what is to say, detailed specifications that define the geometry, composition, and optimal operating parameters of a specific part of a more complex system that is the micro-turbine. The distance between having the design of a rotor and having the design of a micro-turbine that can be commercialized among end-users is not negligible at all. First of all, the rotor should be integrated in the rest of the system, which requires a major engineering effort. In second place it would have to go through a homologation process from whose tests might be inferred the need for making modifications in the original design or limiting their benefits. This not to mention the cost to industrialize the production. The utility of the optimized design of the rotor lies in the fact that it allows the manufacturer to start its engineering and

production process from a very advanced position considerably decreasing both the cost and the uncertainty of that process.

The term “optimize” covers diverse meanings that refer to different technical properties being able to have each one of them a value or importance conditioned by the circumstances. It can be optimized in efficiency, weight, size, reliability, in angular speed, ease of start-up, simplicity of construction, in economy of manufacture, etc. When the time comes to perform this research it will be necessary to clarify which is the desired optimization because the searching of one could hinder the reach of another. Considering that the machine to design is placed in a static location and that its essential objective is the production of electrical energy it is easy to deduce that optimizing in efficiency is the best option, although weight or size would have to be sacrificed for that purpose.

Conditioned to the success of this first phase, it might be considered the convenience of increasing the R&D endowment before being put on the market to perform a second phase. The objective of this second phase would be a more ambitious design with a bit more complex scheme. As it has already been mentioned, a schema with a single rotor of dynamic symmetry foils foretells advantages thanks to the refrigeration and the efforts compensation, but it will be more difficult to extract notable advantages from the heat recovery effect of the rotor itself. However, if the participation of a second rotor of dynamic symmetry foils is accepted in the schema, circumstances will change. This new rotor could be expressly dedicated to the recovery of residual energy acquiring here the heat transference a great importance. This second research phase would have as a goal achieving a major milestone, offering an alternative functional scheme to the combined cycle with steam, but this time without the need of using water, evaporators and condensers, and all this applied to a small power generator.

5.5. Risks

The most obvious and immediate risk is failure. It has already been described the objective arguments to justify the feasibility of the dynamic symmetry philosophy to design gas turbines and that justify the expectations. But without the R&D phase to obtain one or more designs with manifestly enhanced performances it would not be able to link to this technology an approximate quantification of the achievable improvements. This research phase could lead to a too poor result as to consider attractive the change of designing and manufacturing paradigm. In addition, it must never be ruled out in an absolute manner the possibility of a catastrophic failure caused by an unexpected cause. Other possible difficulties during the research phase are also predictable. The unexpected drop of an important member of the team, the choice of an initial path that leads to a result of insufficient quality, the malfunction of some of the employed tools, or simply a mistake, are harmful events that will cause delays, additional costs and demoralization. A good planning and project management and having contingency plans are the weapons with which to minimize these risks and mitigate their consequences.

The institutional sabotage is a concept that would enclose a group of practices, some legal and some illegal, directed to hinder any procedural or process involving some type of public

administration. A denial of credit or grant, a delay in the concession of a permit or license, some insurmountable certification and homologation tests, a stormy judicial process, a campaign of defamation and discredit, revelation of privileged information, selective persecution, espionage. If the technology of the dynamic symmetry turbines is finally no use at all then there will not have to worry about these risks. But if on the contrary, the evolution of the project shows that it is a technology capable of producing some impact in the competitive panorama of the target industry then it must be considered a real risk. The lobbying, the cronyism or simple corruption could be behind the obstacles to let a disruptive innovation access to a determined market in terms of fair competition with powerful actors already established.

In the industry of gas turbines, where manufacturing processes are highly sophisticated, building a rotor of dynamic symmetry foils is not a technological challenge. Nevertheless, the architectures derived from the dynamic symmetry criterion are move largely away from the conventional so that the risk to find in the market a resistance to the change of paradigm for purely psychological reasons exists. The best way to minimize that risk is to demonstrate through research objective and significant advantages with regard to existing solutions and to look for a strategic alliance in the industry to facilitate the realisation and distribution of the final product.

So far, the patent application procedure, with its international search report completely favourable, and the exchange of opinions with some experts seem to confirm that the dynamic symmetry turbines are a global innovation. But not even the granting of patent in all countries where it is requested is an absolute guarantee that it may not appear in the future a conflict by which it could be proved by means of legitimate grounds the breach of the patentability requirements which today seem to be clear. Apart from this possibility, never ruled out, there is a risk of suffering some kind of contingency related to the legal defence of patent rights. The attempt to challenge a patent or to undermine it distorting its claims by a competitor is one of those contingencies. The statistics provided by the patent offices indicate that they are unusual conflicts, but they warn that they are associated to patents of high scientific and economic value. A piracy situation or some kind of patent violation may arise, but by the market configuration and by the clearly distinguishable characteristics of the innovation it seems to be an unlikely risk. In order to combat these risks it is necessary to be well informed, to take precautions and to have sufficient resources to embark upon legal battles.

The emergence of new technologies able to displace total or partly to others in use is an inevitable risk. Technology, by its own nature, is condemned to become obsolete. The technical field of energy generation is one of the most active in terms of R&D. Even so, by the information available, in the current industrial context gas turbines are considered as a technology with an encouraging future. This is not to say that, in the hypothetical case that this project was successful, no other emerging technology would completely displace the dynamic symmetry turbines. Being an uncontrollable risk, having a good policy of technological surveillance and competitive intelligence is what will permit to anticipate the consequences.

6. Business Plan

6.1. Model

The business project will have as the main economical activity the commercialization of exploitation licenses for the technology of dynamic symmetry turbines and related engineering services. The licenses can refer both to the direct exploitation of the patent as to the exploitation of designs elaborated in the company. In the short term, the company will have the configuration of an office, it is a simple infrastructure, little problematic from the safety and occupational risks point of view, and easily detachable. In the medium term a laboratory for prototyping and physical testing may be incorporated to the infrastructure. The essential organizational structure of the company would be as follows:

- Direction: Will be responsible for strategic planning, fiscal management and accounting, human resources, institutional relations, R&D policy, competitive intelligence, legal, corporate image…
- General Services: Will be responsible for ensuring the availability of work resources through preventive and corrective maintenance on the facilities.
- Engineering and production: Will be responsible for researching and developing the technology as well as to give advanced technical support to customers. In general the production of this unit will be intangible assets such as technical documentation, software, and industrial designs or other engineering services that customers may demand. In the medium term, components for gas turbines and testing services in the laboratory could be commercialized.
- Marketing and purchasing: Will be responsible for relations with intermediaries and customers, as well as with suppliers.

The short-term approach is structured in two phases. The start-up phase, characterized by the provisional nature, will include the minimal tasks and investments required in order to be able to decide whether to continue with the project. The continuation phase involves providing the company with a more stable infrastructure and the beginning of the commercial activity. Taking into account the pretended activity and that the target market is clearly international in scope, the geographical location of the company is a circumstantial factor of low criticality.

6.2. Start-up phase

It will have as objective to establish the necessary means to carry out the initial research, as commented previously, that allows highlighting the advantages of the dynamic symmetry turbines and making viable its subsequent introduction in the market. The start-up phase is, virtually, the beginning of the normal activity of the company. Although it has been named research, due to the uncertainty of its result, the certain thing is that this initial research for the start-up phase is perfectly comparable to the engineering work that should be performed with the company in normal operation to obtain a

licensable design to commercialize. However, after the hypothetical success of the initial research, similar future engineering works are no longer named researches in spite of being equally submitted to the possibility of failure. The start-up phase is the one to determine the initial minimum investment for this technology-based business project. The infrastructure required for this phase will be similar to that of the company in its final conception, but at a greatly reduced scale exclusively adapted to the needs of the start-up phase in order to minimize the economic risk. In the pessimistic, but likely hypothesis, that it was impossible to count on the valuable participation of an industrial ally or a consultant to provide the specialized engineering function, the tasks to execute will be:

- Research consisting on the optimized design of the rotor of dynamic symmetry foils corresponding to a micro-gas turbine in recuperative cycle with a shaft power of 100 kW.
- Recruitment of research personnel to carry out the task of research.
- Election and acquisition, or rental, of the software tools appropriate to the research task.
- Election and acquisition, or rental, of adequate computer equipment to perform the research.
- Lease of an office in which the research and administrative tasks specific to the activity could be performed.
- Management for the entry in the PCT national phase in those countries where it is desired to obtain patent protection.
- Knowledge management and development of workbooks.
- General administration.

Obviously this list of tasks is not a detailed or final planning of the start-up phase. In particular, it could be extremely interesting locating an engineering services provider with sufficient capacity to carry out the research avoiding this way the direct recruitment of staff, of technical means, or even of the office. It is also likely that the research is completed before the deadline for entry in the national phase. Achieving this is important in case that the research is unsuccessful and it is decided not to continue with the project, what is to say, not to enter the PTC national phase saving the corresponding costs.

The estimations of cost concepts are based on prudent and plausible hypotheses, but they are tentative and they can all be changed by knowledge or subsequent circumstances or by convenience of the participating partners in the project. These are the hypotheses considered:

- It is not taken into account public aids, entrepreneurship support, discounts or any other type of advantages.
- The company is located in the Community of Madrid (Spain). Its location is provisional and does not need to be enabled for representation functions nor visits reception.
- Prices have been consulted or estimated in the first semester of 2013 with local suppliers and are expressed without VAT.
- The promoter of the project performs control functions, knowledge management and punctual technical support with part-time dedication.

- The researchers are university post-graduates with experience and the employment relationship is of limited duration renewable according to the requirements.
- It is not taken into account travel expenses or any kind of allowances for the staff.
- The calculation software is of the brand ANSYS (academic license).
- An administrative manager will be responsible for the formalities of constitution, plan of occupational risks, staff recruitment, etc.
- A patent agent will be responsible for the processing of the patent.
- For prudential reasons it is expected the entry in the PCT national phase for the following countries: United States, Canada, Japan, European Patent (Germany, France, United Kingdom, Italy, Austria, Spain, Switzerland, Sweden, Norway, Belgium, Finland, Greece, Ireland, Netherlands, Poland, Portugal, Turkey), Brazil, Russia, India, China, Australia, South Korea, South Africa, Ukraine, Mexico.
- It is assumed a period of 3 months since the full availability of resources until the company has an operational infrastructure.
- It is assumed that research requires 6 months.

Cost concepts list relating to the establishment of the company and the means to carry out the initial research. For each item it is indicated the number of units (U), the description of the concept, the unit price in euros (€/U), the period of time to which is referred the price in months (m), the first month of imputation of the cost (M1), the last month of imputation of the cost (M2). The period of time will be left empty when it is about a fixed cost attributable once; months of imputation are referred at the beginning of the start-up phase:

U	CONCEPT	€/U	m	M1	M2
1	Administrative management agency fixed costs	5000		1	1
1	Administrative management agency variable costs	100	1	1	9
1	Office 50 m²	600	1	2	9
1	Office conditioning	1000		2	2
1	Insurance	150	12	2	9
1	Utilities	200	1	2	9
1	Promoter	2500	1	1	9
2	Researchers	5000	1	3	9
2	Scientific software licenses	27200	12	2	9
2	Computers	3500		2	2
1	Another computer equipment	2500		2	2
1	Provision for other expenditure	7000		1	1
1	Entry in the PCT national phase	60000		1	1

6.3. Continuation Phase

The success of the research corresponding to the start-up phase will provide a marketable design and, what is more important, a perception of technical and competitive advantage. Once overcame the initial incredulity, the time has come to offer the design under license and to start an income-generating activity for what it will also proceed to reconfigure the company by providing it with a more definitive infrastructure to give continuity to the project. Engineering and R&D will be part of the normal activity of the company. Taking advantage of the sureness achieved after the initial research it may opt to develop a fully operational technological demonstrator or begin a second phase of research to generate an even more disruptive second design. The size of the company will continue being reduced, but enough to perform all organizational functions of its final conception. In any case, the success of the start-up phase will lead to a situation of less uncertainty that will facilitate subsequent decisions necessary so that the project will evolve into a state of sustainable activity in the time. The specific objectives of the continuation phase will be:

- Leasing and enabling an office in which all the activities of the company including the commercial one could be performed.
- Recruiting personnel to perform the new functions.
- Hiring consulting services for intermediation and legal advice in the establishment of the licensing agreements.
- Giving publicity to the design obtained in the previous phase and to its benefits among the potential customers in order to formalize license agreements.
- Giving continuity to the engineering function inherited from the start-up phase while maintaining or improving their human and technical resources and its budget of variable costs.
- Defining a solid growing strategy for the company. Among other things, the strategy should consider diversifying in the implementation of the human and technical resources that, by its nature, can engage in missions that go far beyond the gas turbines engineering covering other fields of knowledge.

The hypotheses considered in the continuation phase are:

- The promoter is the executive director.
- It is assumed a duration of 24 months for the continuation phase.

It is anticipated the following list of concepts of costs relating to the continuation phase. The months of imputation are referred to the beginning of the start-up phase:

U	CONCEPT	€/U	m	M1	M2
1	Administrative management variable costs	200	1	10	33
1	Office of 100 m²	1000	1	10	33
1	Office conditioning	8000		10	10
1	Insurance.	250	12	10	33

1	Utilities	400	1	10	33
1	Promoter	5000	1	10	33
2	Researchers	5000	1	10	33
1	Administration Assistant	3500	1	10	33
2	Scientific software licenses	27200	12	10	33
1	Other software tools	20000		10	10
1	Supplies, external services and other costs of the activity	2000	1	10	33
1	Provision for other expenditure	50000		10	10
1	Patent Maintenance	40000		10	10

6.4. Summary

Ignoring potential income and computing a margin of deviation in the overall budget of the 33% it is established the following summary of the investment required to launch the project:

PHASE	€
Start-up phase	176850
Continuation Phase	717700
Patent Costs	100000
Margin of deviation	330000
TOTAL	**1324550**

It is considered advisable to have a large accessibility fund for legal contingency.

7. Promoter

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