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Optimization Model for Economic Evaluation of Wind Farms - How to Optimize a Wind Energy Project Economically and Technically[1]

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ABSTRACT: This paper makes a review and systematize methods and techniques of economic evaluation applied to renewable energy projects, specific to wind energy projects. Both project and cost methodologies of economic evaluation are reviewed for a model optimization construction for a proposed optimization model with its objective function most appropriated. It is necessary to engage in different approaches, but complementary, microeconomic project evaluation methods and optimization methods applied to engineering solutions in wind energy converter systems. Optimization model for economic evaluation of wind farms can be as an efficient planning and resource management, which is the key to the success of an energy project. Wind energy is one of the most potent alternative energy resources; however the economics of wind energy is not yet universally favorable to place wind at a competitive platform with coal and natural gas (fossil fuels). Economic evaluation models of wind projects developed would allow investors to better plan their projects, as well as provide valuable insight into the areas that require further development to improve the overall economics of wind energy projects.

Keywords: Optimization model; Economic evaluation; Wind energy projects; RE projects management.
JEL Classification: Q42, C61

1. Introduction

Interest in the use of renewable energy sources has grown dramatically during the last decade, largely as a reaction to concerns about the environment impact of the use of fossil and nuclear fuel. However, the subject of renewable energy is of far wider interest than to environmental issues alone. The use of fossil and nuclear fuels is so central to industrialized societies that any examination of the difficulties they cause or their potential solutions raises a wide range of issues: of the technology and design, politics, social structure, economics, planning and even history. This is an area in which there are many views, of varying degrees of insight and expertise, but little certainly.

One of the most exciting aspects of the study of renewable energy is that it is inherently positive. It is an area which offers the possibility of solutions to some of society's most difficult problem. Again, this appears most clearly when a broad approach is taken. Thus the study of renewable energy involves much more than the technical possibilities of replacement of fossil and nuclear fuels. Some of the major scientific areas of interest are:

i. *Environmental science* – the comparative impact of fossil, nuclear and renewable energy sources on the atmosphere, waterways, and the plant and animal life on the earth. This

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includes considerations of the greenhouse gases effect, acid rain and pollution of the seas. Related issues include the dynamics of climate ant its relationship to the biosphere.

ii. *Earth sciences* – the origins of and physical principles underlying the various forms of renewable energy.

iii. *Technology* – the design and implementation of renewable energy based technologies, and their integration with existing technologies and distribution systems. Related issues include the technical possibilities for improving the efficiency of present energy use, in buildings, machinery, appliances, power plants, etc.

iv. *Social sciences* – the technological/economical/social/philosophical issue of large-scale systems versus small-scale local systems. The difference between the relatively concentrated reserves of fossil fuels in some countries and the wider distribution of renewable energy resources has major political implications and may influence patterns of industrialization and economic development. Changing fuels prices have a dramatic effect upon the world´s economies.

v. *Planning* – the sitting of power stations, transmission lines, wind farms, tidal barrages, biomass plantations or hydroelectric plant, which has a major planning impact, with legal and social implications. Transport planning, too, is intimately related to the mix of fuels and other energy sources available.

vi. *Architecture, building and design* – the design of buildings and neighborhoods for energy efficiency and to incorporate integrated energy supply systems which mix renewable and others sources.

As can be notice, study renewable energy sources and technologies it is necessary an multidisciplinary understanding, so the way these projects can be measure or optimized take us to a body of knowledge for a complete and more comprehensive analysis of a power station planning and management, case of wind farms, at a microeconomics view.

To optimize a wind farm, each aspect and typical assumption must be challenged and carefully evaluated. The challenge in the evaluation has been determining the life-cycle economic implications of aspects such as lost availability, losses at full load, and no-load losses so they can be included in the design process. Three economic factors condense the complexities of the wind farm business model into a form that can be conveniently used in simple spreadsheet calculations to optimize techno-economic power plant for maximized profitability (Maddaloni, 2005). These factors can be determined from the unique economic characteristics of the specific project, including wind regime, cost of money, tax treatment, and expected project return on investment.

Wind energy investment decisions are driven by economics, not necessity. The wind farm must have the lowest possible total lifecycle cost for the project to maximize its economic potential. A specific design choice may have a complex effect on the project financial performance, affecting capital costs, taxes, insurance, energy revenue, maintenance costs, and government subsidies. A method is required to simplify the calculations so that alternate design proposals may be compared and an optimal solution chosen based on the specific economic and engineering factors of the particular wind farm project.

An optimal solution is a result of an optimization process. Optimization is an important tool in decision science and in the analysis of physical systems. To use it, we must first identify some objective, a quantitative measure of the performance of the system under study. This objective could be profit, time, potential energy, or any quantity or combination of quantities that can be represented by a single number. The objective depends on certain characteristics of the system, called *variable*s or *unknowns*. Our goal is to find values of the variables that optimize the objective. Often the variables are restricted, or constrained, in some way (Nocedal & Wright, 1999).

The process of identifying objective, variables, and constraints for a given problem is known as modeling. Construction of an appropriate model is the first step — sometimes the most important step — in the optimization process. If the model is too simplistic, it will not give useful insights into the practical problem, but if it is too complex, it may become too difficult to solve. Once the model has been formulated, an optimization algorithm can be used to find its solution. Usually, the algorithm and model are complicated enough that a computer is needed to implement this process. There is no universal optimization algorithm. Rather, there are numerous algorithms, each of which is made to a particular type of optimization problem. It is often the user's responsibility to choose an algorithm that is appropriate for their specific application.

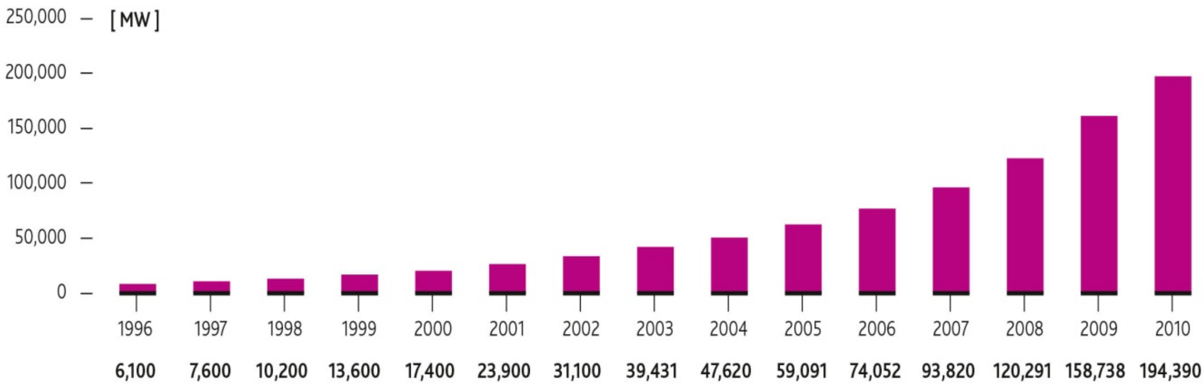
The cost of energy, that has to be minimized by changing the design variables and others parameter influence cost of energy such as wind speed, wind farm layout, wind production losses, O&M cost parameters and control parameters. The optimization must maximize the profit obtained during the useful lifetime of the wind farm studied.

2. Literature Review

The availability of electrical energy is a precondition for the functioning of modern societies. It is used to provide the energy needed for operating information and communication technology, transportation, lighting, food processing and storage as well as a great variety of industrial processes, all of which are characteristics of a modern society. Because the energy for many of the technologies, systems and possibilities that are a property of the developed world is provided as electricity, it can be presumed that there is a link between the level of penetration and consumption of electricity on the one hand and various properties of a society on the other. The relation between economic and societal development and electricity consumption is bidirectional. The availability of electricity greatly facilitates industrialization, because electricity is a convenient way to replace human power by other sources of energy, which are converted into electricity for transmission, distribution and consumption (Slootweg, 2003).

There exist other electricity generation technologies using renewable primary energy sources that do hence not involve the disadvantages of nuclear and thermal generation. Examples are wave and tidal power, solar power and wind power. In wave and tidal power plants, energy is extracted from the waves and from the water flows caused by the tide. In solar power plants, consisting of solar panels, sunlight is converted into electricity, whereas in wind turbines, the energy contained in flowing air is converted into electricity (Rosa, 2009). One technology to generate electricity in a renewable way is to use wind turbines that convert the energy contained by the wind into electricity. The wind is an infinite primary energy source. Further, other environmental impacts of wind power are limited as well. Although they affect the scenery visually and emit some noise, the consequences of this are small and ecosystems seem hardly to be affected. Further, once removed, their noise and visual impact disappear immediately and no permanent changes to the environment have occurred. A wind turbine generates the energy used to produce and install it in a few months so that the energy balance over the life cycle is definitely positive (Kennedy, 2005; Oliveira, 2010b). According to Global Wind Energy Council (2011a) the growth of wind power during the last decade in the world. The global cumulative installed of wind power capacity is growing approximately exponential over the past five years, annual growth has been above 30%.

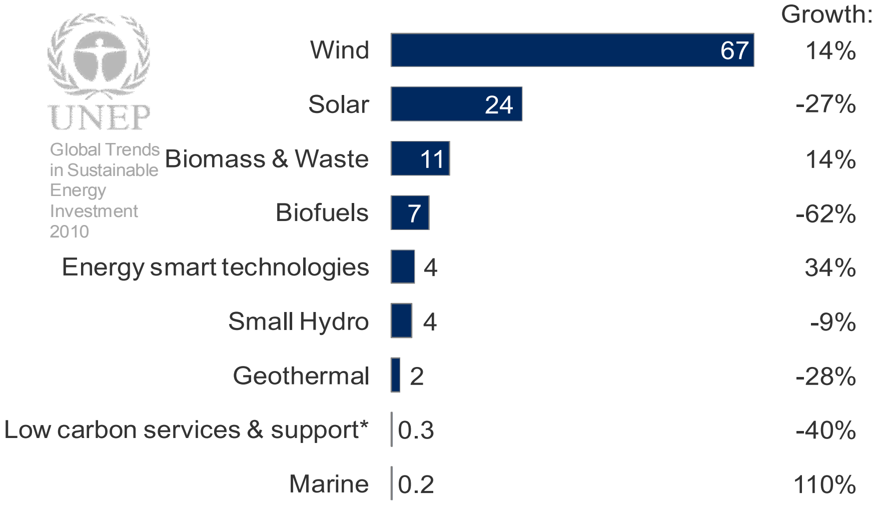
Figure 1. Global cumulative installed wind capacity (1996-2010)



Source: Global Wind Statistics 2010 (GWEC, 2011a)

Wind was even more dominant as a destination for investment in 2009 than in the previous year. In 2008, it accounted for $59 billion or 45% of all financial investment in sustainable energy, but in 2009, its share rose to 56%. Total financial investment in wind last year was $67 billion, compared with $119 billion for all sustainable energy technologies (SEFI, 2010).

Figure 2. Financial new investment ($bn) and growth by technology 2008-2009



Source: SEFI/Bloomberg New Energy Finance (SEFI, 2010).

The strength of wind reflected several developments. One was the financial go-ahead for a number of large offshore wind farms in the North Sea, notably the 1GW London Array, the 317MW Sheringham Shoal project and the first, 165MW phase of Belwind. Another was that, in uncertain economic and financial circumstances, wind was seen as a relatively mature and therefore lower risk, sub-sector of clean energy than some others (SEFI, 2010).

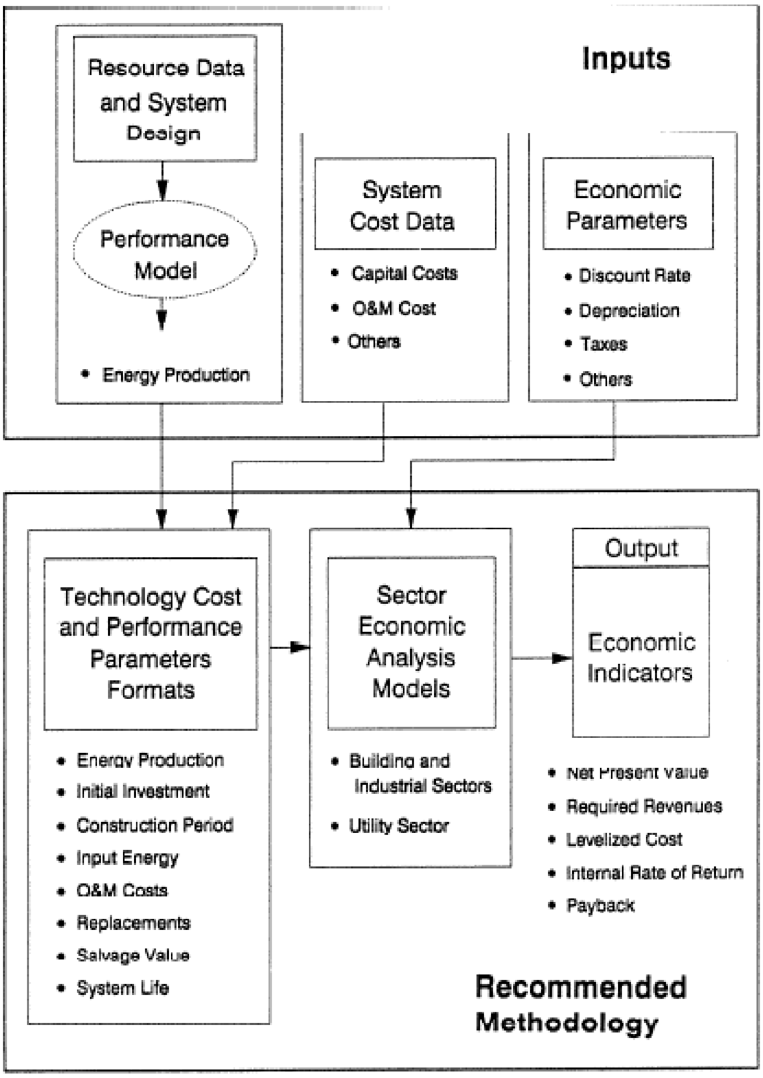
According to Wagner and Epe (2009) to promote wind energy, the research needs need to be identified and the research work carried out. Initially, there are such environmental and social challenges as integration into the landscape, noise impact, bird flight paths, life cycle analysis and sustainability. And of course, wind turbine and component design have to be improved continually, *i.e.* basic research in aerodynamics, structural dynamics, dynamic forces, new materials, feasibility studies into new systems, generators using permanent magnets, gear boxes, etc. For planning and building wind turbines and wind farms, commonly accepted certification procedures must be formulated and standardized. For an optimized grid integration of wind energy, especially in great quantities, power quality can be supported by better forecasts of wind resources and by the use of storage sites.

El-Kordy et al. (2002) evaluation of the economics of energy systems strongly depends on the four cost factors: capital cost; maintenance cost; fuel cost; and external cost, when considered. Fuel and external costs are sensitive to fuel type and efficiency of the used system. Economic parameters such as discount, inflation and escalation rates, deeply affects the evaluation. Future sums of money must be discounted because of the inherent risk of future events not turning out as planned, the present worth method being considered as a suitable tool for comparing the different alternatives.

The International Energy Agency (1991) developed a guideline for the economic analysis of renewable energy technology applications that can be summarized as in the Figure 3. The IEA´s recommended methodology represents a consistent, structured, generalized approach which is appropriated for feasibility analysis for both public and private sector. The Figure 3 shows the relationship between the inputs, costs, performance formats and sector analysis models. The entire economic indicator will be discussed ahead.

For Gökçek and Genç (2009), the calculation of the electrical energy generation cost, all payments required for the installation of the power plant must be known. The cash flow for the project includes the expenditures such as land, construction, fuel and operating and maintenance. In general, in power plants, cost per unit energy is calculated by dividing the amount of energy produced to the total expenditures made along the certain time interval. The levelized cost of electricity (LCOE) is one of the most important indicators for evaluating fiscal performance of power supply systems such as wind energy conversion system (WECS). The LCOE is a technique applied by the techno-commercial analysts to calculate the unit cost throughout the economic life of the project. The levelized cost for WECSs can be describe as the ratio of the total annualized cost of the WECS to the annual electricity produced by the system.

Figure 3. Diagram of recommended economic analysis approach



Source: IEA/Guidelines for the economic analysis of renewable energy technology applications (IEA, 1991, p. 12).

A techno-economic analysis of electricity generation from wind energy made by Arslan (2010) discuss about Life-Cycle Cost analysis for onshore wind farm connected to a grid which essentially includes two main components, which are the investment and the operation and maintenance (O&M) costs. The investment cost includes the costs of the turbine, foundation, grid connection, and civil work. The environmentalist economists maintain that the real cost of a process must be calculated by adding to the investment and operational costs the cost of the damages to both human health and nature.

Zhang et al. (2010a) introduce a new concept for economic evaluation of wind farms. Its formulation is based on cost of energy (COE) optimization. The result showed that *(i)* the profitability is particularly sensitive to changes in the capital cost, the capacity factor, the electricity escalation rate, and the initial installation cost; *(ii)* the profitability is slightly less sensitive to changes in the O&M cost; and *(iii)* the impact of the turbine rated power and the inflation rate is limited.

Nouni et al. (2007) developed the levelized unit cost of electricity (LUCE). The LUCE is one of the commonly used indicators for financial performance evaluation of renewable energy based decentralized power supply systems. Total annualized cost is calculated by taking into consideration the capital costs of the different sub-systems of the SWEG project and its annual operation and maintenance cost.

The National Renewable Energy Laboratory (NREL) (1995) compiled a *Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies* that provides guidance on economic evaluation approaches, economic measures, while offering a consistent basis on which analysts can perform analyses using standard assumptions for each case. It not only provides information on the primary economic measures used in economic analyses and the fundamentals of finance but also provides guidance focused on the special considerations required in the economic evaluation of renewable energy projects.

Oliveira (2010b) makes an overview about the indicators of attractiveness and risks like simple payback (SPB), discounted payback (DPB), net present value (NPV), internal rate of return (IRR), benefit-to-cost ratio (BCR) and required revenues (RR). Also are discussed about some indicator of cost analysis in energy projects just like LCOE, total life-cycle cost (TLCC), net present cost (NPC), levelized electricity generation cost (LEGC) and unitary present average cost (UPAC). A simulation studied with these indicators concludes that they must be used as *tool kit* for wind energy project economic evaluation. The indicator studied is not recommended be applied alone, better combine the indicators in function of the evaluation objective.

There are many software available in the market that can be possible to make a sophisticated economic evaluation of an energy project for both renewable and efficiency application. We can cite the *RETScreen® International Clean Energy Project Analysis* used as an investment tool decision, the HOMER energy software applied to dimensionate a power system with all its features for the system works as it must be. It is possible to make a list of software used professionally by engineers, designers, economists and related professions.

The cost of the renewable technology can be evaluated by its cumulative production, research, development aspects. Many authors such Kobos et al. (2006), Ibenholt (2002), Lund (2006), Neij (1999, 2008), Pan and Köhler (2007) and Sorensen (1997). For onshore and offshore wind energy technological aspect and its improvements have a great impact on cost reduction of wind energy project analysis. It is an important aspect to be considered.

Efficiency planning and resource management is the key to the success of an energy project. Wind is one of the most potent alternative energy resources; however the economics of wind energy is not yet universally favorable to place wind at a competitive platform with conventional energy (fossil fuels) (Zhang, et al., 2010a). The optimization model for economic evaluation of wind farms, developed in this research, would allow investors and managers to better plan their projects, as well as provide valuable insights into the areas that require further development to improve the overall economics of wind energy.

As we can notice there is exhaustive list of authors, institutions about economic evaluation methodologies and approaches applied to energy projects. Each methodology and approach has its own objective, although they usually highlight economic merits only – in an energy project it is also interesting engineering and physics variables. In economics view it is necessary that the project could remunerate its costs and create profits for investor as well as any other economic agent involved. In the other hand, in engineering aspects, the project must be dimension ate according to its equipments, utilities and machinery used in the power station. How is it possible to optimize a wind farm, in a project conception, in both economical and engineering point of view?

Both onshore and offshore wind energy has had a growth during the last decade in the world and the importance of renewable energies technologies is more and more emphasized by public authorities because climate change and global warming is a concern for modern world, so methodologies which could become investment in this kind of technology more safe with dynamics analysis will be welcome.

Wind energy is one of the renewable technologies that is becoming more and more competitive at the global level, but has not received enough attention on optimization process for economic evaluation of wind farms by the researchers in both economic and engineering aspects. Indeed, most of the optimization models reflects aspects of Engineering and Physics sciences, but in the economic view has not been analyzed in the depth that it deserves. So, try to develop an optimization model for economic evaluation of wind farms using algorithm genetic it is a step ahead for economic evaluation methodologies, and we hope in few years could applied this new approach for better decisions and make that invest in renewable energy projects is right and secure way to explore the resources from nature, help the economy growth and the environment protection.

3. Wind Energy Economics

There is not a single price and cost of energy for wind farms. Both depend on the location, size and number of turbines, in addition to being influenced by political incentives or subsidies granted by governments. The initial investment costs - cost of equipment, feasibility study, installation, and O&M are essential to determine the final cost of the technology. In general, the main variables that make up the production cost of wind energy are the investment costs of fuel and operations and maintenance (Morthorst & Chandler, 2004; Wizelius, 2007).

In the case of wind power there is no dependence of the cost of fuel, but the investment cost is still higher than that of conventional sources. However, the costs of wind farms are decreasing, indicating that this trend is likely to continue due to several factors such as the development of larger turbines and more efficient, technological advancement, reduction in the cost of O&M, among others. An extremely important factor that contributes to raise the cost of wind power is its capacity factor, generally around 30% to a maximum of 40%, while conventional plants varies between 40% and 80%. The cost of electricity generation by wind in Europe declined in the last 15 years approximately 80%. At the same time, the installed capacity has increased exponentially in scale, from less than 100 MW to 34,400 MW in 2004. During the past ten years the price of wind turbines decreased by 5% each year, while at the same time revenue increased by 30% (Zervos & Kjaer, 2008).

Despite the reduction on the costs in recent years, some problems still there are hindering investments in wind energy projects. When connecting a wind farm to the electricity grid transmission, it is needed to check the power factor, voltage and final production of harmonics caused by the turbines, and investment costs are still higher than the conventional power plants of oil and natural gas. Moreover, the presence of wind turbines may threaten birds and cause visual and noise impact (Gipe, 1995; Heier, 1998).

With regard to wind energy production, economic optimization and evaluation of projects in renewable energy, it is also needed on other factors, such as potential exposure from this source in the energy world, especially in regions where wind speeds are expressive. As the output power is extremely sensitive to wind speed, variability significantly impacts on financial investments and O&M costs. Given to this, it is highlighted the importance of developing assessment methodologies for economic and financial evaluation and management for energy projects considering the uncertainties associated with this type of technology (EWEA, 2009a).

Both onshore and offshore wind energy minimizing the cost per kWh produced it is necessary because when it is going to be sold to the grid, the high and variable cost of wind energy represents a real risk to the investor or wind farm promoter. So when a wind farm is evaluated by deterministic indicator such as NPV, IRR, SPB, DPB and others economic and financial indicator usually applied for it, but such evaluation reflects a set of parameters adjusted and assumptions considered in order to show the results for a unchangeable market situation. In Economics Sciences it´s called *"ceteris paribus"*.

On the other hand, the wind energy system and green energy markets have some inherent features that should be taken into consideration. As renewable energies have been receiving supports by government's incentives such as production tax credits (PTCs), modified accelerated cost recovery system (MACRS) and others finance supports which become wind energy technology competitive comparing to conventional ones and other renewable energies technologies. However, given the fast growth of wind power during the last decade and the expectations for the future, wind power penetration levels may increase to levels where engineering and economic optimization for this kind of system starts to be more and more necessary. Note that in this thesis, the optimization model is defined as a suggested methodology able to evaluate a wind farm in both economical and engineering aspects.

According to Benatiallah and Dakyo (2010) the main objectives of the optimization design are power reliability and cost. Minimizing the total cost, we can achieve an inexpensive and clean electric power system. In addition, the proposed method can adjust the variation in the data of load, location. Various modeling techniques are developed by researchers to model components of Wind system. Performance of individual component is either modeled by deterministic or probabilistic approaches. The economic study should be made while attempting to optimize the size of integrated power generation systems favoring an affordable unit price of power produced. The economic analysis of the wind system has been made and the cost aspects have also been taken into account for optimization of the size of the systems. The total cost of system takes into account the initial capital investment, the present value of operation and maintenance cost, the inverter replacement cost and the wind system replacement cost.

The key objectives of the researches have been to find the lowest cost and highest reliability design of a wind farm. Developing methodologies with approaches for structural and economic optimization of onshore and offshore wind farms are still a challenge due to its multivariable nature and its non linear behavior. The importance of using new optimization techniques for short-term energy planning is due to the existence of multiple uncertainties (Fleten, Maribu, & Wangensteen, 2007).

For Baños et al. (2011) the investment decision on generation capacity of a wind park is difficult when wind studies or data are neither available nor sufficient to provide adequate information for developing a wind power project. Some researchers have analyzed in detail how to determine the probable wind power availability at a given site according to historical wind velocity data, and its capacity to meet a target demand.

At the start of this research work, the primary concern was about the correlation between wind velocity and cost of energy produced at a specific site, but after an extensive literature review it became clearly that a economic evaluation by classical economic engineering approach considering deterministic indicator such as discounted cash flow technique would not be sufficient. It is a multivariable problem and engineering aspects must be taken into consideration. The central question for this research work is hence: *How to optimize a wind farm economically and technically by the application of nonlinear algorithm theory for minimizing the cost of energy? Is it possible?*

4. Methodological Approach

The overall approach taken to reach the research objective was to investigate the formulation and logics of the various evaluation models/indicators, each model has its own variables and relations to explain the results and objectives for each model studied. At first, it checks only the economic models and then engineering evaluation models are analyzed with its objectives too. According to the central question or this research, it is an industrial problem and the steps to follow may be considered as follows (Frederick S. Hiller & Lieberman, 1995):

1. *Define the problem of interest and gather relevant data* – Why is there dissatisfaction with the present operations and what alternative courses of action appear to hold most promise of being effective solutions to the problem, relative to a set of pertinent objectives. The size of a wind farm project and the size of the wind turbine itself will vary depending on the amount of electricity the developer intends to generate. Costs of components per unit size tend to decrease as size increases, and through economies of scale, the construction costs per unit manufactured decreases as more wind turbines are manufactured (at least to the point where equipment and personnel are adequate). However, because the mass of the wind turbines' materials increases at a cubic rate to its rotor diameter, and the power rating increases with the square of its rotor diameter, there will be a critical size that increases the cost per kW of maximum power (Johnson, 1985). As wind energy is an intermittent source of power, this fact gives rise to extra costs in generation, distribution and transmission, as well as the cost associated with the intermittency of wind.
2. *Determine a suitable "measure of effectiveness" (often called the "objective function) to be optimized* – the wind energy industry is capital intensive, so wind parks' investment must be returned at an expected rate at investor point of view. Usually, the wind park promoter (manager) needs to overcome some technical and economical issues about sub operation which has to be maximized or certain costs minimized. Thus, most optimizations are economic optimizations.
3. *Elaborate a model to represent the system whose optimization is desired* – A model may be defined as a device, physical or symbolic. Models are almost always necessary in industrial work since experimentation with full-sized industrial equipment disrupts production and is very costly in money and time. And sometimes industrial equipment is only contemplated in design or as replacements. Usually, the most desirable model is the mathematical model, which employs mathematical statements to represent the system and enables responses to be calculated rather than be measured. The measure of effectiveness is expressed as a function

of a set of variables at least one of which is subject to control. (The variables involved are often functionally interrelated so that they behave similarly to the active variables in the realistic system simulated.) As the variables are manipulated, their effectiveness in optimizing the objective is changed. Often there are restrictions imposed on the values of the independent variables, or functional restraints involving these variables, and such restraints are expressed by supplementary equations and/or in equations.

4. *Solve the problem* – Determine the values of the independent (controllable) variables which optimize the objective (i.e., maximize the effectiveness of the system) subject to any restraints imposed on the system (equipment limitations, rigid management policy, operating limitations, minimum quality characteristics, market restrictions, legal limitations, etc.).
5. *Test the model and calculated solution obtained from it* – If adjustment is indicated, readjust the model, determine a new solution, and check again. A carefully chosen initial model may eliminate difficulties here.
6. *Establish controls* – The lack of effective control over certain variables might seriously invalidate the appropriateness of the original model. The need for a change in the original controllable variables to offset changes in uncontrollable variables must be recognized and a new optimum solution found.
7. *Implement the suggested solution* through appropriate organizational channels, and establish a set of operating procedures so that those concerned with control of the operation can attain the optimum as easily as possible.

It proved necessary to investigate the various aspects of a microeconomics view, as a power station unit, because when it is studied separately, it is necessary to understand the wind system conversion, its electro-mechanical, layout and economical restrictions. As it has been said about wind farms, the intermittency must be considered into economic evaluation methodologies, fundamental difference can be found when the intermittency is not considered. It was hence impossible to draw conclusions with respect to the isolated impact of the intermittency effect, because it was made dynamic simulation and the conclusions had to be qualified for the minimum cost of energy and other economic indicators being used.

The widely used *RETScreen* software, version 4, a tool for analyzing the technical and financial viability of potential renewable energy projects is now being used by more than 35,000 people in over 196 countries around the globe (RETScreen® International Clean Energy Decision Support Centre, 2008) was also used for the research. At the start of the research project, it was quickly found that there was not a unique methodology or optimization procedure model included in the standard libraries (products and projects database) of this software. Further study showed that at that time, this also needed to other dynamics simulation packages, and that wind technologies available are based only on manufactures´ information. It was therefore inevitable to adopt another methodology for optimization process and try dynamics simulation by nonlinear algorithms.

Finally we studied extensively Theory of Nonlinear Optimization and take advantage of practical aspects of the simulation approach, as well as the manipulation of variables and its results. Then, we developed an optimized technology and calculated the best economics results for a hypothetical wind energy project. A preliminary validation of the developed model was carried out using different combinations of wind technologies available by products database of *RETScreen* software. It is important to say again, the software does not make dynamics simulations, only deterministic and probabilistic calculations.

5. Conclusion

Practical realization of the general methodological approach to financial and economic analysis and efficiency evaluation of the investment projects in renewable energy technologies (wind energy) requires a sufficiently vast database including legal, reference, marketing, technical, and other information about the project itself and the conditions for its implementation. Most of this information (especially that referring to the future) is of prognostic nature and is not sufficiently full and precise, which tells on the feasibility estimates and project efficiency that depend on the realization conditions. In view of importance of this problem, much attention is paid to the methods of financial and economic analysis and efficiency evaluation of the investment projects in the context of risk and uncertainty. Choice of particular methods to analyze investment project risks depends on the factors such as the project scale, completeness of the information base, requirements on the depth of analysis and degree of project reliability, and so on.

In a real economic sector, practical analysis of projects, unfortunately, is often carried out in an uncertain environment because the available information base is insufficient for determining the probability of one or another event (condition, index, and so on) with the desired precision. Then, informal methods become the main tools to support the decision making. It is often proposed to rely on the subjective data about the technical and economic parameters of a project that are based on the expert opinion. Precision and validity of these data depend on the expertise of the experts. Popular is the method of analogies where the necessary information is obtained by analyzing the design estimates and accounts of similar, already realized projects. However, these analogies mostly provide distorted results because each project has its own specific features.

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