RISK IDENTIFICATION IN LARGE PHOTOVOLTAIC PLANTS' CONSTRUCTION PROJECTS

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Spanish energy policy has been changed several times from 2007. The current legal framework leads to a higher complexity in the administrative process in renewable energy projects. This situation has created a new scenario in terms of uncertainty management. All this, coupled with the large budget of such facilities, requires the realization of a preliminary risk analysis.
The first part of this article is a summary of the State of the art and a review of the various existing methodologies for the risk analysis in projects with uncertainty.
For the risk identification in construction projects for large solar photovoltaic plants, we start on the knowledge and both national and international experience acquired by four experts in solar photovoltaics energy projects.
To check the functionality of the model, a case study of the construction project of a solar photovoltaic plant of 286.9 MW located in the town of Jumilla (Spain) is developed.

Keywords: Risk identification; Photovoltaic; Hierarchical structures

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La política energética española ha sido modificada varias veces, desde 2007. El actual marco legal conduce a una mayor complejidad en la tramitación administrativa en proyectos de energía renovable. Esta situación ha creado un nuevo escenario en términos de gestión de la incertidumbre.
En la primera parte del presente artículo se realiza un resumen del estado del arte y una revisión de las distintas metodologías existentes para el análisis de riesgos en proyectos con incertidumbre.
Para la identificación de los riesgos en proyectos de construcción de grandes plantas solares fotovoltaicas, se parte del conocimiento y la experiencia adquirida por cuatro expertos en proyectos de energía solar fotovoltaica tanto nacional como internacional.
Para comprobar la funcionalidad del modelo, se aplica a un caso de estudio de un proyecto de construcción de una planta solar fotovoltaica de 286,9 MW ubicada en la localidad de Jumilla (España).

Palabras clave: Identificación de riesgos; Fotovoltaica; Estructura jerarquica

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1. Introducción

Since the adoption of the RD law 1/2012 by the Spanish Government, on 27 January, whereby proceeds to the suspension of the pre-allocation proceedings and suppression of economic incentives for new utilities from renewable energy sources, cogeneration and waste, renewable energy sector and more particularly, photovoltaic energy stay in a lethargic point.

The absence of a regulatory framework specific for photovoltaic solar energy introduces a new variable which, coupled with the intrinsic of major energy construction projects, requires a risks identification to which the project can expose.

From a generic point of view, different risk definitions are available in the literature, the first one perhaps the most appropriate for photovoltaic projects:

- The exposure to the possibility of economic or financial loss or gain, physical damage or injury, or delay, because of the uncertainty associated with pursuing a particular course of action (Perry and Hayes, 1985; Chapman and Ward, 1997).
- The probability of losses in a project (Jaafari, 2001; Kartam and Kartam, 2001).
- The likelihood of a detrimental event occurring to the project (Baloi and price, 2003).

According to the PMBOK® Guide 5th Edition 2013, an effective risk management involves a four-phase process:

1. Risk identification: the process of determining which risks may affect the project and documenting their characteristics.
2. Risk assessment: the process of risk's prioritization for further analysis or subsequent actions, assessing and combining the probability of occurrence and impact.
3. Risk response: the process of developing options and actions to improve the opportunities and reduce threats to the project's objectives.
4. Risk supervision and review: the process of implementing plans in response to the risks, tracking down identified risks, monitoring residual risks, identifying new risks, and reviewing the evolution of the initial risks.

This article focuses on the first phase, since they will study procedures for the risks identification in a construction project for large photovoltaic plants, leaving for future research, analysis and risks evaluation and the rest of phases, most related to the construction phase of the project.

2. Methodology for the risks identification.

A model of risk identification is proposed. The model consists of three stages:

1. Establish an experts group for the risks identification.
2. Identify risks sources.
3. Build a hierarchical structure with the identified risks to facilitate further analysis.

2.1. Establish a group for the risks identification.

The members of a risks identification group must be carefully selected. Selected experts will have a high degree of knowledge and previous experience in similar renewable energy projects (Hu and Zou, 2011).

The risk assessment team must include at least the following experts: project managers, members of the team project, developers, and experts in the subject from sources outside of the project team or interested parties.

In this article, the risk identification panel is made up of four experts with extensive experience in photovoltaics constructions projects.

- E1: Project Manager, with extensive experience in the design and construction of solar photovoltaic plants.
- E2: Promoter of facilities for production of electricity from renewable sources.
- E3: Manager of a photovoltaic construction projects company under EPC mode.
- E4: Head of O&M department solar photovoltaic plants.

2.2. Identify risks sources.

The risks identification aims to detect in advance enough all those factors that may affect the project, in order to eliminate or reduce the negative risks and enhance positive risks or opportunities.

Correct risks identification is essential since the rest of risks management processes, such as risk analysis and risk response strategies, may only take place on the identified potential risks.

The identification of risks is an iterative process present throughout the project life cycle because the risks may evolve or appear new risks as the project advances. The frequency of iteration depends on the characteristics of the project.

There are some useful methods for the experts group to identify the potential project risks, such as checklist, influence diagrams, cause and effect diagrams, analysis of the failure mode and its effects, fault trees and event trees (Yim et al., 2015; Ahmed, Kayis and Amornsawadwatana, 2007, Chapman 1998).

2.3. Build a hierarchical structure with the identified risks

The members in the risk assessment group are required to identify and classify the risks associated with the construction project (Nieto-Morote and Ruz-Vila, 2011). To decompose the risks into adequate details in which they can be efficiently assessed, a risks hierarchical structure is generated (Zhu et al., 2015), (Klein and Cock, 1998).

The risks are sorted into n groups based on the risks types, as shown in Fig. 1.

The state of the art contains several risks classifications (Athanasios, Read and Ioannou, 2016) (Zhao and Li, 2015), (Serhat, 2011), (Aragonés-Beltrán et Al., 2009), (Millera and Lessardb, 2001). Along with the experience and qualification of the risk identification panel, a first general classification of risks is created:

1. Political Risks.
2. Technical Risks.
3. Economic Risks.
4. Delay Risks.
5. Legal Risks.
6. Social Risks.

A questionnaire in two phases is completed by the experts' panel. In the first phase, experts must respond to the following question: *"Based on the general classification of risks, identify the possible general conditions that may affect the project for each of them"*.

The second phase focuses on the identification of all project´s specific risks. The question that the experts must answer is, *"for each of the subgroups of risks that form the hierarchical structure, identify, and describe the risks that may arise in the project".*

As a result, a hierarchical risks structure of three levels will be obtained.

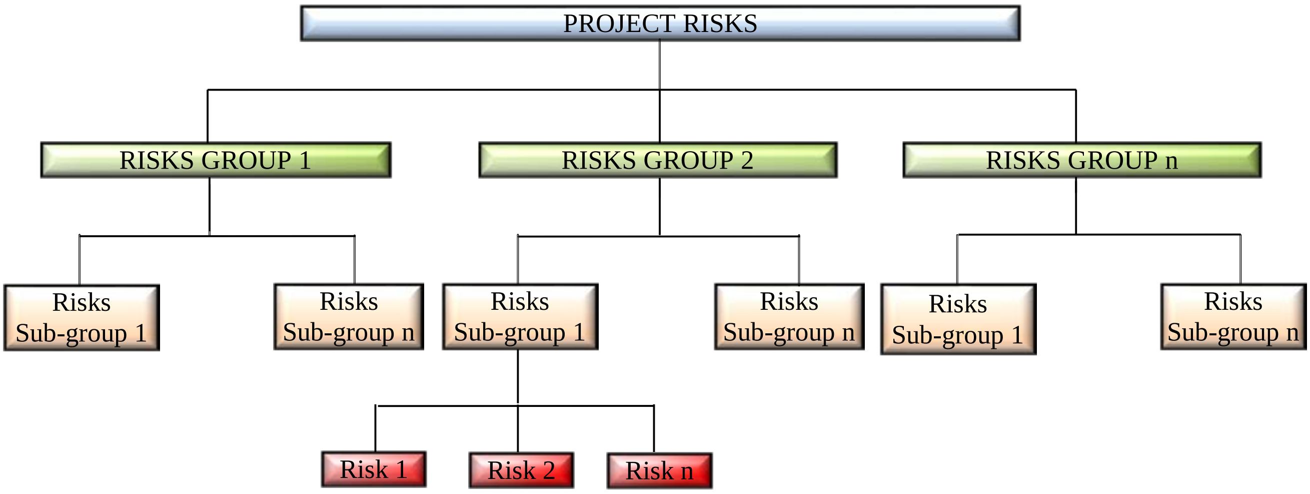

Fig. 1 Generic risks hierarchical structure.

3. Case study.

A real project of a 286,9 MW photovoltaic plant located in Jumilla (Murcia) serves for the risk identification development model. This plant actually is in phase of study and initial processing. General technical characteristics of the project are:

- Extent by the solar field: 692 HA
- Amount of photovoltaic panels: 1.062.600 panels with 270 Wp c.u.
- Support photovoltaic panels structure: fixed structure with an 25º tilt angle and an 0º azimuth, with kneeling Monopole system.
- Power Inverter: 180 investors from 1,590 kVA/c.u.
- First level of rising tension: 180-transformation station of 1.600 kVA/c.u.
- Underground internal distribution networks to connection the transformation stations.
- Park substation: formed by three positions of 100 MVA/c.u., tension rises 30/132 kV.
- Airline evacuation on 132 kV and 12 km in length.
- Transformer substation in connection with transportation of REE: formed by a position of 300 MVA 132 kV to 400 kV tension rises.

The technical and administrative project complexity is very high; the occupied area is very extensive, with a great impact on the social, economic, administrative and environmental surroundings.

The project duration is a key objective, the project delays are important risks that they must evaluate. Furthermore, other risk sources may lead to the project delay, as the lack of supply quality, design changes, lack of resources.

3.1. Political risks.

The policy influence is not only national, also the role of Councils in obtaining the appropriate licenses for the construction of such facilities is very important.

3.1.1. Macroeconomics.

This group of risks encompass the associated with the influence of European renewable energy policy.

Currently, this type of project is located within the European Plan known as 20-20-20: at 2020, each of the Member States should achieve,

- Reduce their consumption by 20%.
- Reduce greenhouse gas emissions by 20%.
- 20% of you generated primary energy must come from renewable energy sources.

However, the Member States such as Spain have freedom to regulate the markets of renewable energy as they see fit to achieve these goals. Actually, the influence of utilities companies over the Spanish government has blocked the photovoltaic development.

Table1. Political Risk. Macroeconomic risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
1.- Political risks	1.1- Macroeconomic	1.1.1.- Level of political stablity	Spanish Government stability
		1.1.2.- The change in energy policy	Energy policy changes introduced by Spanish government

3.1.2. Urban planning.

Councils authorize the urban licenses, construction licenses and activity license, zoned plan and final license. These licenses have a technical component, but it is finally the Town Council which grants licences. Jumilla is a medium spanish village, and this projects pays a lot of money for the licenses, therefore the council is very interested in the project.

Table 2. Political Risk. Urban planning Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
1.- Political risks	1.2- Urban Planning	1.2.1.- Approval by the Local Body	The level of the interest in the project by the Jumilla Council.
		1.2.2.- Obtaining of construction license	Interest of Jumilla Council to grant the license.

3.2. Technical risks.

3.2.1. Plant location.

A correct plant location selection is essential for a good success of the project. This project is located at the V radiation area, according to the CTE DB-HE (2006), the greater radiation Spanish area, with a 300-500 l/yr rainfall level, not especially stormy.

The land is an agricultural slightly wavy area that today is dedicated to the vineyard, it can affect production due to the shadows between the panels.

Table 3. Technical risk. Plant location Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
2.- Technical risk	2.1.- Plan location	2.1.1.- Technological climate change adequacy	Climate changes along the project life cycle may affect.
		2.1.2.- Flood and storm risks	Possibility of strong storms and floods in the project area.
		2.1.3.- Estimation of effective solar radiation	There is always an error index in the estimates of solar radiation.
		2.1.4.- Earthworks	Technical problems associated with land levelling.
		2.1.5.- Earthquake	Murcia is an downturn earthquake zone.
		2.1.6.- Geotechnical study	Risk associated with geotechnical problems.

3.2.2. PV technology.

The main generation components selection of the photovoltaic installation such as photovoltaic modules, structure support, power inverters, is a key to the successful achievement of the project, and entails certain risks. The initial plant design is with polycrystalline panels, fixe structure, inverters stations and connected to the REE grid. Close to the photovoltaic plant are several wind power plants.

Table 4. Technical risk. PV Technology Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
2.- Technical risk	2.2.- PV techonology	2.2.1.- New PV solar power systems	Risk in the development of new PV technologies.
		2.2.2.- PV cell selection	Inadequate selection of the polycrystal panels can affect the profitability.
		2.2.3.- Inverters selection	Risk associated with the selection of the inverters.
		2.2.4.- Support panels structure selection	Influence of the material selection.
		2.2.5.- Connection to the electric grid	Requires expensive and accurate technical control systems.
		2.2.6.- Alternative power generation systems	Risk from the new power generation systems development.

3.3. Economic risks.

As investment project, evaluation of economic risks is transcendental, even more in the case of a real investment project valued at 270 million euros.

3.3.1. Plant exploitation.

The plant operation is the most delicate phase from the economic perspective, since it is the phase in which the cash flows necessary to make financing payments and benefits expected for the project occur.

Table 5. Economic risk. Plant exploitation Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
3.- Economic risk	3.1.- Plant exploitation	3.1.1.- Plant operation cost	Risk of uncertainty at operational costs.
		3.1.2.- Corrective maintenance costs	Risk of higher or lower plant corrective maintenance costs.
		3.1.3.- Prevention maintenance costs	Risk of preventive maintenance costs.
		3.1.4.- Performance losses	Bad estimation PV plant performance losses.

3.3.2. Plant location.

The plant location is essential for the possible revenues from production, as well as the possible costs associated with the nature of the land where it is located.

Table 6. Economic risk. Plant location Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
3.- Economic risk	3.2.- Plant location	3.2.1.- Errors in estimating the effective solar radiation energy	Lack of consistency in the estimation of effective solar radiation energy.
		3.2.2.- Revenue estimation due to the climate change	Climate change along the plant life cycle.
		3.2.3.- Earthworks resources	Risk of extra expenses associated with the corrective measures for vineyard levelling.
		3.2.4.- Flood prevention works	Risk of extra expenses due to problems associated with flood
		3.2.5.- Solution of geotechnical problems	Risk of extra expenses due to geotechnical nature problems.

3.3.3. Plant star-up permits.

Regarding the connections and start-up of power generation installations, payments and economic agreements to perform the installation determine an important factor in profitability.

Table 7. Economic risk. Plant start-up permits Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
3.- Economic risk	3.3.- Plant star-up permits	3.3.1.- Connection to electric grid costs	The agreement with REE involves strong costs.
		3.3.2.- Agreement costs with landowners	The farmers attitude with new technologies generate problems to sign an agreement
		3.3.3.- Possibility of constructing the power connection infrastructure	The connection point to the grid is the REE responsibility, but it is possible that the promoter can build it.
		3.3.4.- Construction license	City Council may require specific items to obtain the construction license.

3.3.4. Technology.

A wrong selection of technology to use in the main photovoltaics components may be a significant cost in the installation and lack of performance.

Table 8. Economic risk. Technology Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
3.- Economic risk	3.4.- Technology	3.4.1.- Costs due to inadequate PV cell selection	It would mean a reduction in the plant profitability.
		3.4.2.- Costs due to inadequate inverter selection	It would mean a reduction in the plant profitability.
		3.4.3.- Costs due to lack of consistency in the support panels selection	Costs associated with the repair of the polycrystal PV panels structure support.

3.3.5. Macroeconomics.

The macroeconomic changes can produce serious risks on the future of the project, since they directly attack the plant profitability. Spain is a country of extremes, easily affected by global macroeconomic variations: If the banking community has a problem then Spain requires a economic rescue but if banking community have liquidity generated a boom; if a there are a world economic growth Spain is at the forefront of that growth, and if there is an economic crisis Spain is leading the fall. Should also be taken into account the Spanish electricity market, very unstable.

Table 9. Economic risk. Macroeconomic Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
3.- Economic risk	3.5.- Macroeconomic	3.5.1.- Bank financing	Risk associated to the obtaining bank financing.
		3.5.2.- Changes in power demand	Changes in power demand varies the profitability.
		3.5.3.- Inflation	Influence of the inflation rate on the project cash flow.

		3.5.4.- Changes in energy prices	Risk of energy prices varying during the PV plant lifespan.

3.4. Time delay risks.

3.4.1. Connection to the electric grid.

The connection to the electric grid can produce delays that affect the project.

Table 10. Time delay risk. Connection to the electric grid Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
4.- Time delay risks	4.1.- Connection to the electric grid	4.1.1.- Delays in obtaining administrative approval for the connection infrastructure	It will depend on project support by the administration of the Region of Murcia.
		4.1.2.- Construction delays of the power connection infrastructure	The construction by the promoter is faster than if REE built it.
		4.1.3.- Delays in obtaining PV plant Start-up Act.	Also depends on project support by the administration of the Region of Murcia.
		4.1.4.- Delays in the agreement signature with REE and CNMC	There is a delays risk in the signing of economic contracts with REE and CNMC.

3.4.2. Urban planning.

The urban planning depend directly on Jumilla council and Murcia Governments, and constitute prior permissions for the beginning of construction, together with the administrative authorization. Unjustified delays granting the licenses directly affect the projects profitability, with losses for the promoters, since all processing costs prior to the urban license are covered by own funds.

Table 11. Time delay risk. Urban planning Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
4.- Time delay risks	4.2.- Urban planning	4.2.1.- Delays in obtaining the Local Body Approval.	Administrative delays in the project approval by the Jumilla Council.
		4.2.2.- Delays in obtaining approval of the environmental impact.	Administrative delays associated with the approval of the project's environmental impact assessment by the Murcia Goverment.
		4.2.3.- Delays in obtaining the construction license	Administrative delays in the construction license approved by Jumilla Council.

3.5. Legal risks.

3.5.1. Legal issues.

Spain is a country with legal guarantees, but macroeconomic circumstances affect the reversals in the energy strategies, introducing legal changes affecting projects.

Table 12. Legal risks. Legal issues Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
5.- Legal risks	5.1.- Legal issues	5.1.1.- Specific legislation changes	Legislative changes risks affect the incentives to renewable energies.
		5.1.2.- General legislation changes	Risk of changes in Spanish general legislation, both technical and administrative.

3.5.2. Connection to the electric grid.

All the rules for connection to the electric network facilities are subject to changes and updates. Being the electrical connection a key for the operation and profitability of the plant, it is necessary to identify what risks may be associated with it.

Table 13. Legal risks. Connection to the electric grid Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
5.- Legal risks	5.2.- Connection to eletric grid	5.2.1.- Legislative changes in the Administrative Authorization of the power connection infrastructure	Power connection infrastructures requires Administrative Authorization by Murcia Government.
		5.2.2.- Legislative changes in the Startup Act permits.	Murcia Goverment gives the Start-up permit at the end of the project construction.
		5.2.3.- Obtaining the electrical registration for production facilities	Risk of changes in the legislation of RAIPEE.

3.5.3. Urban planning.

It is identify all risks associated with regulatory and legal changes in the Jumilla Town hall.

Table 14. Legal risks. Urban planning Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
5.- Legal risks	5.3.- Urban planning	5.3.1.- Legislative changes in the Local Body Approval	Risk of change in Jumilla planning regulations.
		5.3.2.- Legistaltive changes in the Enviromental Impact Approval.	Risk of change in the environmental impact law, both national and regional level.
		5.3.3.- Legislative changes in the Construction License	Risk of change in the Jumilla urban standard.

3.6. Social risks.

In identifying the project risks, the bigger the scale of the project, greater influence has on society.

3.6.1. Plant exploitation.

The project includes the installation of a complete anti-intrusion security system on the plant.

Table 15. Social risks. Plant exploitation Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
6.- Social risks	6.1.- Plant exploitation	6.1.1.- Theft	Risk of theft at the power plant site.
		6.1.2.- Vandalism	Risk of vandalism at the power plant site.
		6.1.3.- Terrorism	Islamist attacks in Murcia Region.

3.6.2. Social impact.

Spanish society is very involved with the introduction of renewable energy in their daily lives, like the Jumilla people where there are photovoltaic plants since 2006.

Table 16. Social risks. Urban Planning Risks.

GROUP	SUB-GROUP	RISK	DESCRIPTION
6.- Social risks	6.2.- Social Impact	6.2.1.- Social consequences resulting from land acquisition	Risk of social disapproval from Jumilla citizens.
		6.2.2.- Social acceptance	Plant impact on previous owners

4. Conclusions.

In this work, a risks identification model arise based on the work of an experts group by the main professional profiles necessary for the construction of large solar photovoltaic plants. Once identified, risks form a hierarchical risks structure of three levels.

To test the adequacy of the model, it applies to a real project of construction of a photovoltaic solar plant of 286.9 MW in Spain. As part of implementation model, there is a risk identification panel, made by four experts, such as the promoter, the Project manager, the Manager of a company specializing in construction of photovoltaic plants and a responsible for operation and maintenance.

To collect the experts identification work, it has been used the Delphi method with a two-tier questionnaire which has been implemented. Based on a general classification of risks (political, technological, economic, time delays, legal and social), experts have identified sixteen sub-groups which make up the second level of the hierarchical structure. At the second questionnaire phase, they have identified fifty-six risks that may occur in construction of the photovoltaic solar plant.

The final outcome is a hierarchical risks structure of three levels. The hierarchical risks structure will be the basis for future research that develops the following stages of risk management for the construction project, such as risk assessment, risk response and risks monitoring and control throughout the project life cycle.

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