Risk analysis for renewable energy projects due to constraints arising

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Abstract. Starting from the target of the European Union (EU) to use renewable energy in the area that aims a binding target of 20% renewable energy in final energy consumption by 2020, this article illustrates the identification of risks for implementation of wind energy projects in Romania, which could lead to complex technical implications, social and administrative. In specific projects analyzed in this paper were identified critical bottlenecks in the future wind power supply chain and reasonable time periods that may arise. Renewable energy technologies have to face a number of constraints that delayed scaling-up their production process, their transport process, the equipment reliability, etc. so implementing these types of projects requiring complex specialized team, the coordination of which also involve specific risks. The research team applied an analytical risk approach to identify major risks encountered within a wind farm project developed in Romania in isolated regions with different particularities, configured for different geographical areas (hill and mountain locations in Romania). Identification of major risks was based on the conceptual model set up for the entire project implementation process. Throughout this conceptual model there were identified specific constraints of such process. Integration risks were examined by an empirical study based on the method HAZOP (Hazard and Operability). The discussion describes the analysis of our results implementation context of renewable energy projects in Romania and creates a framework for assessing energy supply to any entity from renewable sources.

1. Introduction

The study begins form the fact that Romania, through National Authority for Energy Regulation (ANRE), it was employed in fast mode in the EU Directives regulations, due to its specific characteristics, by being among the first countries in the Member States, which transposed in their legislation EU Directives on renewable energies [1]. The share of renewable energy production is indicated by Directive 2009/28/EC, setting mandatory targets for renewable energy for all EU Member States and which establishes that Romania must increase the amount of renewable in its energy mix from 17.8% at the end of 2005 to 24% by 2020 [2]. According to the European strategy 20/20, through which the European Union (EU) established mandatory targets to be achieved by 2020 for a 20% overall share of renewable energy in the EU [2]. Starting from the 20/20 strategy, aimed at addressing the problem of identifying and exploiting every area of Romania, which has a large potential to
achieve this target. Romania, however, has a highly diversified geographic relief and consequently to achieve the 20/20 strategy creates challenges for wind energy development projects, operating in geographically isolated regions, but potentially suitable for wind. Implementation of wind power projects lead to a complex process based on best techniques with the implications of quality raw materials that correspond to specific technical requirements. Bottlenecks in wind power supply chain can be overcome by applying the right technologies. The risk arising from the development and implementation of such projects is very high, due to the combination of several determinant factors. The study addressed in this paper examines the risks that may occur along the life cycle of such projects. Based on the experience of implementing such projects and given the fact that these risks are diversified, the research team has identified and systematized them in a conceptual model. As well, the research team identified bottlenecks in wind power supply chains based on a wind farm project developed in Romania in isolated regions with different particularities, hill and mountain locations in Romania, having difficult climatic conditions at certain times of the year.

![Figure 1. Risk assessment – conceptual model](image)

The development of renewable energy projects require complex knowledge and particularly much more experience in many fields: Mechanical structures and wind turbines (MSWT); Electrical machines (EM); Power electronics (PE); Automatic controlling strategies (ACS); Project management and administrative problems (PM). All these teams are specialized in developing and implementing
specific integrated conceptual model for identifying major risks, which may be expressed over the project life cycle (Figure 1). Each risk factor was identified and analyzed in particular. The study of this paper focuses on the stage 3 of the conceptual model shown in Figure 1, specifically on how to identify constraints in the supply chain of manufacturing of generators, respectively on the right methodology of analyzing this risk factor.

2. Constraints arising

Usually made of fiberglass, the nacelle contains: 1. the gearbox that increase the low rotational speed of the rotor shaft in several stages to the high speed needed to drive the generator; 2. the brake system that consists in disc brakes that bring the turbine to a halt when required; 3. the generator that converts mechanical energy into electrical energy; 4. the yaw system, consisting into a mechanism that rotates the nacelle to face the changing wind direction; 5. the power converter that converts direct current from the generator into alternating current to be exported to the grid network; 6. the transformer that converts the electricity from the turbine to higher voltage required by the grid; and 7. the pitch system that adjusts the angle of the blades to make best use of the prevailing wind. The study is focused on the generator manufacturing, taking into account that the size of turbines has been increasing dramatically from less than 1 MW up to 2 MW and larger [3]. This means, that the number of generator suppliers who can satisfy the demand reliably is reduced considerably. Increasing capacity involves a huge investments and bottlenecks, and in addition to that, these kind of bottlenecks represent a high risk, taking into account that the generator manufacturing represent 3,44% from the total project cost. The generator (G) is a standard equipment whose main components are steel and copper. It’s not as easy to increase the generator manufacturing capacity as it is with other components, because there are necessary a lot of equipment [3].

In this approach the research team after strong an action research in wind power projects implemented and based on the methodology Theory of Constraints (TOC) using Drum-Buffer-Rope (DBR) strategy identified bottlenecks for the generator manufacturing supply chain, more exactly for some important materials, taking into account the distribution for raw materials (copper and steel), necessary for the generator manufacturing.

The bottlenecks represent an excess of inventory or insufficient or poor raw materials because the fluctuations are inconsistent.

A solution to avoid bottlenecks in a wind power supply chain is done using an intermediary buffer at every link in the chain. In this way each link will be able to manage individually an intermediary stock, placing orders at the right time. An addition to the proposed solution is given by the fact that the links in the supply chain must focus more on obtaining sustainable cooperation between supply activities regarding the movement of necessary and special raw materials for wind components in the chain. The impact of all bottlenecks can largely be mitigated with appropriate combinations of industry and policy measures. In order to mitigate supply chain bottleneck is applied TOC-DBR philosophy which implies dimensioning some intermediary buffers at each link such this intermediary stock can ensure continuous high precision materials according to design specifications.

2.1. Drum-Buffer-Rope philosophy

The DBR method is designed to optimize a flow process, obtaining the full capacity of the most constrained capacity link (CCL) in the supply chain. The rhythm of CCL represents the drum for the rest of the system. The rope represents the mechanism of releasing the raw material into the flow process, protecting the CCL from being swamped with “work in progress” [4]. The rope regulates the rate of inserting the raw material into the flow process. The inserting rate is no faster than that impose by the drum. The rope is connected with the drum with the help of the safety buffer that protects the CCL from starving because of the work during the process. The TOC method through DBR helps to move important raw materials (cooper and steel) in supply chain in safety stocks that are placed and dimensioned to protect the rhythm of each individual link in the chain. The purpose of using DBR
solution for dimensioning intermediary buffer has the role to protect the links in supply chain against bottlenecks variation occurred within the chain, with the condition to keep the movement rhythm of the project at each link in the supply chain. Dimensioning intermediary buffer through DBR philosophy is done according to the following steps [4], [5]:

1. Is identified each link rhythm (D-Drum) in the study of this paper is about test medium consumption / link supply chain;
2. Is dimensioned an intermediary stock (B-Buffer) in front of each link in the chain (Figure 2) which can create link protection, regardless of orders variation that can occur;
3. Buffer dimensioning is made on three levels (green, yellow and red) (Figure 2) in such a way that placing orders decision to refill the buffer must fulfill the following:
   - while the consumption rhythm keep the buffer on green is not created another command;
   - when the buffer reaches yellow the order is created and validated (it is send to refill the buffer) so that by correlating link consumption rhythm (Drum) with delivery lead time (DLT), the buffer must be refilled during the period when he is at the red level. This is the stage where the replenishment valve rope is pull, also called the rope mechanism (R-Rope). DBR helps provide at every time raw materials for a wind power creating safety stocks that are placed and dimensioned in order to ensure fluency tests included in the phase of project cycle development. The levels divided into colors have the result that technical testing of pieces that need to be integrated in component manufacturing must fulfil correctly the specific requirement.

![DBR philosophy](image)

**Figure 2.** Wind power supply chain and its bottlenecks

To illustrate further the philosophy DBR it is configured a buffer dimensioning for two components (copper and steel). In this regard the DBR method avoid the bottlenecks through adjustment created by each link rhythm (D-Drum), respectively a dimensioning algorithm of the three decision levels (Figure 3) (B-Buffer, R-Rope). Buffer dimensioning is divided into three areas: the top has green status, the middle has yellow status and the bottom has a red status (Figure 3).
Target buffer (Tb) represent the maximum level of the buffer, where:

$$Tb = DLT \cdot \frac{MC}{UDLT} \cdot SP$$  \hspace{1cm} (1)

DLT - delivery lead time  
MC - medium consumption, on  
UDLT - measuring unit delivery lead time  
SP - safety percentage  

The Status buffer (Sb) refers to the buffer stock level at a time. Further status buffer is calculated for yellow in percentage rate (Sb_{yellow}), which will generate the order release, respectively for red status buffer (Sb_{red}) in percentage rate. Sb_{red} has the significance of buffer level in which pulling is generated „ROPE”, more specific, the entrance of the new stock in buffer. The status buffer for red (Sb_{red}) is calculated based on the test medium consumption daily (TMC_{daily}), (Table 1).

| Buffer Dimensioning for copper and steel | MC | DLT   | SP   | Tb   | Sb_{yellow} | Drum     | Sb_{red} | Rope   |
|----------------------------------------|----|-------|------|------|-------------|----------|----------|--------|
| Copper                                 | 25 | 1 week| 125% | 31   | 80.64%      | 3.57/day | 11.52%   |        |
| Steel                                  | 100| 1 week| 125% | 125  | 80%         | 14.28/day| 11.42%   |        |

3. Risk analysis  
The scientific study of this work is further supported by the method HAZOP (hazard and operability) to analyze the degree of risk for each factor separately identified. HAZOP method was introduced to define and delineate the principles required to perform interoperability studies and risk analysis, due to the growing complexity of processes that cannot be examined using conventional methods [6]. For example the first step in Table 3 shows the probability of occurrence for each risk factor separately, for example, the factor no. 6 (Table 2) - "Manufacturer can delay the completion of the works".  

According to the analysis performed in this study, this is a high risk factor for the projects, and also taking into account the relatively high probability of occurrence, it must be considered.

Regarding the probability of occurrence of this risk factor 6, after the analyses resulted, it has been found the appearance of some delay for the completion of the works, in this phase to one of 5 projects studied, reason which is why it was considered that this factor has probability of occurrence “Moderate/Possible”, namely value 4 according to the scale from Table 3.
Table 2. The project risk factors

| Nr. | Risk Factor |
|-----|-------------|
| 1   | The cost insurance for extreme weather |
| 2   | Increase cost components in short term (panels photovoltaic, wind generators) |
| 3   | Component availability in short term |
| 4   | Repair key components during operation / warranty |
| 5   | Malfunction of turbines or solar panels during construction or putting into operation |
| 6   | Manufacturer can delay the completion of the works for various reasons |
| 7   | Changes in legislation which may have an impact on the project |
| 8   | Financing cancellation |
| 9   | Delays in obtaining construction permits |
| 10  | Thefts may lead an increase in insurance prices |
| 11  | Regulation of installations cancel/recycling |
| 12  | The lack of qualified labor force |
| 13  | Contract interruption with the company which provides maintenance, which lead to a renegotiation of its subsequent |
| 14  | Modules functioning under the parameters declared by the manufacturer |
| 15  | A too high rate of breakdowns can have the effects of increasing the operating costs |
| 16  | Major damage to the turbines/solar panels which can occur during operation |

In the final step the research team analyzed in an individual manner each risk factor of 16, listed in Table 2 and established through estimations based on brainstorming and experience, severity classification Table 4. Through severity classification it is estimated worst potential, consequences
which result from a failure and even affected accomplishment of the project. For exemplification, it is also considered that factor no.6.

Table 3. Probability of occurrence for risk factor no. 6

| Scale | Probability of occurrence | Explanation | Probability of occurrence assigned to risk factor |
|-------|---------------------------|-------------|--------------------------------------------------|
| 6     | Almost certain            | >=75% (1 in 1.33) |                                                     |
| 5     | Likely                    | >=50% (1 in 2)   |                                                     |
| 4     | Moderate/Possible         | >=25% (1 in 4)   | 4                                                   |
| 3     | Unlikely                  | >=20% (1 in 5)   |                                                     |
| 2     | Rare                      | >=10% (1 in 10)  |                                                     |
| 1     | Almost never              | >=5% (1 in 20)   |                                                     |

The analysis of these RES projects is identified the position of each risk factor in the risk matrix (Figure 4) in accordance with individual scales established for the probability of occurrence and severity.

Table 4. Severity classification appearance for factor no. 6

| Scale | Severity classification | Factor 6 classification |
|-------|-------------------------|-------------------------|
| 6     | Sever impact            | 4                       |
| 5     | Major impact            |                         |
| 4     | Moderate impact         | 4                       |
| 3     | Minor impact            |                         |
| 2     | Insignificant impact    |                         |
| 1     | No impact               |                         |

Starting from the 16 factors described within the paragraph, they have to be analyzed as a system. Analyzing only one factor would lead to misjudgment. Furthermore there are some more factors which have to be included in the logic of decision. These factors are chosen based on the project experience of the authors.
4. Conclusions
Risk analysis method presented in this article can be used to evaluate any supply energy entities from renewable sources, useful in order to achieve feasibility study, or even to identify possible measures necessary to minimize exposure to certain risks.

According with the Risk matrix, the factor 6, detailed above is framed in the category of „High” level, it is observed for probability of occurrence (catalogued 4) and impact or (catalogued 4) towards higher levels, which would lead to the classification as "High" factor.

This factor risk reduction can be accomplished effectively through a variety of measures such as:
- To achieve a very detailed monitoring of intermediary buffers, that requires a control mechanism based on constrained capacity link (CCL);
- Orders prioritization based on consumption;
- Signal through color when order must be created, respectively for the moment in which must enter into buffer.

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References
[1] ***ANRE Ordinance 43 /2011, Regulation for GC issue, www.anre.ro/download.php?id=4035
[2] ***Directive 2009/28/EC of European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official Journal L140, 16–62; 5 June 2009
[3] Keith Hays of EER 2007 Wind directions, http://www.altenergystocks.com/assets/Wind%20Directions.pdf
[4] John H Blackstone Jr 2010 A Review of Literature on Drum-Buffer-Rope, Buffer Management and Distribution, McGraw-Hill, New York, USA
[5] Goldratt E M 2003 Production the TOC way (revised edition), North River Press, Great Barrington, USA
[6] Lawley H G 1974 Operability studies and hazard analysis, Chemical Engineering Progress 70 (4) 45–56