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Design and state of art of innovative wind turbine systems

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ABSTRACT

Wind energy using increased dramatically in the last years. Because of that wind turbine design should be improved to increase efficiency. To make wind turbine with the best characteristics and with the highest efficiency it is suitable to analyze factors that are truly relevant to the converted wind energy. Wind turbine innovative design is investigated in this paper by the theory of inventive problem solution (TRIZ) as a systematic methodology for innovation. TRIZ methodology should provide creative conceptual design ideas of wind turbine. The main aim of this work is to show a systematic methodology for innovation as an effective procedure to enhance the capability of developing innovative products and to overcome the main design problems. The TRIZ method will be used in order to eliminate the technical contradictions which appear in the wind turbine systems.

Contents

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1. Introduction

Innovation process is ability to solve inventive problems. The standard procedure is to utilities trial and error steps [1,2]. In 1946, Genrich Altshuller started a statistical analysis of more than two million worldwide patents [3] and he found the main principles on which the technical systems are based. Since then, an algorithm for solving inventive problems has been established. This algorithm leads to the theory of inventive problem solution (TRIZ) [4–6] for all kinds of technical problems.

TRIZ is an algorithm for technical and technological contradiction solving [7]. TRIZ principles provide guidelines for the engineers to think. Although TRIZ can be used as a problem definition tool, its greatest strength lies in resolving contradictions [8–10] and solving problems defined using other techniques.

One of the most popular TRIZ tools is the “40 Inventive Principles” which consists of a group of deducted generic solutions of technical contradictions across many fields [11–13]. Altshuller matrix organizes the principles depending on the contradiction they solve, which makes for an easy handling and positioning of the intrinsic contradiction in the forefront of the problem definition [14–16].

This investigation deals with the elimination of the contradictions that appear in wind turbine systems using inventive principles recommended by the TRIZ method.

Renewable energy and especially wind energy is very promising alternative energy [17–22]. One of the crucial factors for high conversion rate of wind energy is wind turbine design. There is a growing tendency toward a new design of wind turbine in order to adapt itself for the landscape while it becomes popular [23,24]. In scientific literature, it is possible to find different approaches to study and design wind turbines [25–27].

In wind turbine design, the maximization of the power coefficient is of fundamental importance in order to optimize the extraction of energy from the wind [28–30]. The development of new, more reliable and efficient turbines is one way to answer this competitive pressure. The wind turbine structure design includes many considerations such as strength, stability, cost and vibration [31–33]. Wind towers have to sustain continuous vibration-induced forces throughout their operational life [34]. In article [35] was shown that the optimum solutions showing significant improvements in the overall system performance as compared with a reference or baseline design. It is crucial to perform the optimization procedure of the wind turbine design and especially wind turbine tower to minimize vibration-inducted forces [36]. Efficient model for optimizing frequencies of a wind turbine blade in pitching motion was presented in article [37] in order to avoid resonance of the wind turbine design. Reduction of vibration is a good measure for a successful design of blade structure [38]. In article [39] was developed a highly efficient small wind energy portable turbine (SWEPT) in order to reduce vibration. The blades of wind turbine are the most important component of the wind turbine system [40–44]. Because of its special functions, such as high specific stiffness and specific strength, better design ability, high performance of ant fatigue and ant failure, easy integral molding of large-area and wonderful corrosion resistance, reinforced composite material is widely applied in large scale wind turbine blades [45–48].

The analysis, design, and optimization of different aspects of a wind turbine designs have been conducted for several decades [49,50]. Tools like the TRIZ method can help to gain new insights into a highly constrained and complex design space represented by wind turbine development. The main task of this study is to investigate the application of new inventive principles in wind turbine design to ensure high wind energy conversion and safe operation.

2. TRIZ method

TRIZ is a methodology for solving creative problems [51–56]. It is problem solving method and the main TRIZ findings are:

- Evolutions in technologies trends.
- A small number of inventive principles for all innovations starting.
- To remove conflicts in system by inventive solutions.

TRIZ methodology suggests solving technical contradictions which may be expressed as conflict between two parameters. One parameter could be improved and other could be damaged. 39 parameters are identified as it shown in Table 1 [51–56]. By expressing the contradiction with two defined parameters many solutions can be generated. The interpretation of the parameters depends on engineering field.

2.1. Resolving the wind turbine design contradictions by TRIZ approach

Technical contradictions always occurred in any engineering systems. It happens when one system characteristics need to be improved which degraded other characteristics. A TRIZ method offers the solving of the technical contradiction by contradiction matrix. There are four steps in solving of the technical contradictions:

- Step 1: Analyze the problem parameters to determine “feature to improve” and “undesired result”. For wind turbine design the main goal is to improve stability, ease operations, adaptability, automation and etc. In the same time some features must remain constant. For example wright of wind turbine blades, complexity of wind turbine and etc.
- Step 2: Identification of the parameters in Table 1.

The following featured are identified to improve in wind turbine design according to Table 1:

– Stability of the object
– Shape
– Area of moving object
– Ease of manufacture

Table 1
39 Engineering parameters of TRIZ.

39 Engineering parameters of TRIZ	
1. Weight of moving object	21. Power
2. Weight of stationary object	22. Loss of Energy
3. Length of moving object	23. Loss of substance
4. Length of stationary object	24. Loss of Information
5. Area of moving object	25. Loss of Time
6. Area of stationary object	26. Quantity of substance
7. Volume of moving object	27. Reliability
8. Volume of stationary object	28. Measurement accuracy
9. Speed	29. Manufacturing precision
10. Force (Intensity)	30. Object-affected harmful
11. Stress of pressure	31. Harmful side effect
12. Shape	32. Ease of manufacture
13. Stability of the object	33. Ease of operation
14. Strength	34. Ease of repair
15. Durability of moving object	35. Adaptability of versatility
16. Durability of non-moving object	36. Complexity of device
17. Temperature	37. Complexity of control
18. Illumination intensity	38. Level of automation
19. Use of energy by moving object	39. Productivity
20. Use of energy by stationary object	