The TRIZ Give Way to the Wind, and Give the Wind Away
A Repeatable Process for Improving Sustainable Wind Energy Generation

Authors
Isak Bukhman, TRIZ Master, Chief Methodology Specialist, Invention Machine
Stephen Brown, Vice President Strategic Marketing, Invention Machine Corp.

Abstract
Given the fast growing population and the ever increasing consumption of resources it is imperative that breakthrough innovations make alternative energy sources more commercially viable. Wind turbines represent an attractive source of sustainable and environmentally friendly energy. World wind energy capacity has been doubling every three years during the last decade and growth rates in the last two years have been even faster. Yet the technology still needs a higher profile and greater efficiency.

Using the improvement of Wind Turbine Development as a case study, this presentation focuses on a proven and repeatable process that overcomes common TRIZ deployment challenges by showing a workflow and methodology for how to get started working on a problem with TRIZ, how to compliment TRIZ with Value Methodologies for problem identification, and how to leverage internal and external knowledge sources to accelerate concept identification.

Introduction - Wind Turbine Development
The potential for wind energy production is yet to be realized, but holds great promise for as a renewable and environmentally friendly source of energy.

- Wind power is expected to grow at an annual rate of 20% resulting in a total of about 40 000 MW of installed capacity around the world by 2004.
- According to recent study “Wind Force 10” wind power could generate 10% of global electricity by 2020, and create 1.7 million jobs at the same time.
- International installation of 1.2 million MW of wind capacity by 2020 would generate more electricity than the entire continent of Europe consumes today.
- Total wind energy potential in the world is 53 trillion kWh, 17 times higher than the Wind Force 10 goal.
- According to the study the cost of generating electricity with wind turbines is expected to drop to 2.5 US cents/kWh by 2020, compared to the current 4.7 US cents/kWh.
Environmental benefits of the 10% target would be enormous – savings of 69 million
The potential for TRIZ as a high-value problem solving methodology has also yet to be
fully realized, especially in combination with Value Engineering and a fund of targeted
informational resources. But with an effective roadmap to guide the practitioner, the
benefits of combining and deploying these discrete resources and methodologies are
readily attainable. This paper describes such a roadmap and thereby provides a
repeatable process for improving not only sustainable wind energy generation, but a
method for improving virtually any technical system.

Project Description & Initial Situation

We have selected Three-Blades Turbine as a base Turbine design for our research project. The Three-
Blade Turbine is most common, sometimes known as a Danish Concept. These three-bladed wind turbines are
operated "upwind," with the blades facing into the wind. Wind turbine works the opposite of a fan. Instead
of using electricity to make wind, a turbine uses wind to make electricity. The wind turns the blades, which
spin a shaft, which connects to a generator and makes electricity. The electricity is sent through transmission
and distribution lines to a substation, then on to homes, business and schools.
Information Gathering

Identify and define the component structure of the wind turbine

Identify trends of past and present R&D efforts that have contributed to current utility-scale turbine technology
• Improvements in the aerodynamics of wind turbine blades, resulting in higher capacity factors and an increase in the watts per square meter of swept area performance factor.
• Development of variable speed generators to improve conversion of wind power to electricity over a range of wind speeds.
• Development of gearless turbines that reduce the ongoing operating cost of the turbine.
• The general trend is toward wind turbines with maximum power output of 1 MW or more. European firms -- such as Danish companies Vestas and NEG Micon -- currently have more than 10 turbine designs in the megawatt range with commercial sales.
• Wind turbine manufacturers optimize machines to deliver electricity at the lowest possible cost per kilowatt-hour (kWh) of energy.
• Development of lighter tower structures. A by-product of advances in aerodynamics and in generator design is reduction or better distribution of the stresses and strains in the wind turbine. Lighter tower structures, which are also less expensive because of material cost savings, may be used because of such advances.
• Smart controls and power electronics have enabled remote operation and monitoring of wind turbines. Some systems enable remote corrective action in response to system operational problems. The cost of such components has decreased. Turbine designs where power electronics are needed to maintain power quality also have benefited from a reduction in component costs.

**System Functional Analysis**

A functional model of the system is necessary to obtain a proper understanding of system behavior. Each component and function must be defined.
Advanced function analysis allows us to define parameters of functions, their actual and required values, and their dependencies.
The completed full function model will document the system sufficiently to enable the recognition of problematic areas in the system. Additionally, the documented model permits an in depth automated evaluation from a Value Engineering perspective.

Use a matrix to provide a checkpoint confirmation that all functions are identified.
Model Data Device Diagnostic: Component Parameters and rating help define strategies for subsequent changes or simplifications of the system configuration. A variety of criteria can be evaluated in order to select strategies that best align with the project goals.

### Design Simplification Strategy - Trimming Method

- Improves product/process by eliminating low value (problematic) components and redistribution their useful functions between other components.
- Simplifies and reduces the cost of user product/process, while preserving the essential functionality.
- The design variants that results from Trimming will generate different problem statements, if solved, can lead to highly innovative solutions.

**Wind Turbine -> trimming scenario results**

1. Low-speed shaft, Gear box, High speed shaft, Wind wane, Wind direction data, Pitch (mechanism) were trimmed.
2. Stator of AC Generator connects Hub.
3. Hub rotates Stator of AC Generator
**Pre-Problem Selection**

We have selected one problem (pre-problem) for the next stage of the project: The value of the torque parameter, which describes the effect of the action push (rotate) by the wind (wind energy) on the Blades (three), is 2000 Nm. The required value of this parameter is 4000 Nm to provide to increase efficiency of blades. The problem is: How to increase the torque of the Blade?

**Algorithm for Inventive Problem Solving – Part 1**

**INITIAL SITUATION ANALYSIS – Selection of Mini-Problem**
**Algorithm for Inventive Problem Solving – Part 2**

PROBLEM MODEL ANALYSIS - List of resources of space, time, substances, (parameters), and fields

1. Distinctly constructed statement and diagram (model) of the problem

**TRIZ ARIZ-85B - PART 2**

The aim of the second part of ARIZ is an estimation of the available resources, which can be used to solve a problem: resources of space, time, substances, (parameters), and fields:

1. Conflict zone determination
2. Operation time determination
3. Determine substance-field resource (SFR) for the article and tool of the problem along with the considered system environment, and over (overall) systems. Make a list of SFR

**List of resources of space, time, substances, and fields**

to the PART 3

**Algorithm for Inventive Problem Solving – Part 3**

DETERMINATION of IFR (Ideal Final Result) and PC (Physical Contradiction)

**TRIZ ARIZ-85B - PART 3**

The application of the 3rd part of ARIZ should produce a concept of an ideal solution and determine a PC that provides the achievement of an IFR. It is not always possible to obtain an ideal solution but the IFR indicates a direction toward the most patent answer:

1. Write down a formulation of IFR-1
2. Reinforce intensity a formulation of IFR-1 with additional requirements. It must not introduce new substances and fields into the system - use SFR
3. Write down a formulation of a PC on a micro-level
4. Write down a formulation of a PC on a micro-level
5. Write down a formulation of an ideal final result IFR-2
6. Check availability of using the system of standards to solve a physical problem formed as IFR-2

**To other GFIN Modules**
Concepts Evaluation & Selection
We created 32 available solutions for farther development by using TRIZ, Value Engineering, and Informational Fund (Scientific Effects Library, Patent Collections, WEB based information), including:

- 9 - From the Inventive Principles
- 2 - From the Effects Library
- 12 - From the System of Standards
- 9 - From Patent Collections and Web based information

Solutions must be ranked to help decide which ones to research further and implement.
Conclusion - Best Solutions

In total, 6 concepts were ranked as high level available solutions, having the ranking equal or higher than 10, including:

1. **Stator of Permanent Magnet Synchronous Generator**
   - Blades rotate directly Stator of Permanent Magnet Synchronous Generator.
   - Permanent Magnet Synchronous Generator works good for variable blades.

2. **Doubled Propeller – Doubled Blades.**
   - The propeller is contra rotating with a diameter of 4.5 m (14 ft 9 in).
   - It has blades made of advanced composites and pronounced scimitar-like curvature on the leading-edge. It offers increased efficiency under high-speed cruise, and improved acoustics.

3. **Efficient propeller – Efficient blades.**
   - A propeller produces a propulsion that drives an airborne vehicle.
   - Disadvantage: This causes an air stream to be driven back, causing high turbulence. This decreases the propulsion.

4. **Blade in form of Mobius strip.**
   - A blade is fixed on a shaft by means of spokes. The blade is made of elastic material and has the Mobius strip form.
   - Advantages:
     1. The propeller blade in the Mobius strip form is simple in design.
     2. The blade in the Mobius strip form is easy to manufacture.

5. **Variable-rigidity flipper - blade.**
   - Different rigidity is required in swimming flippers under different water conditions (governed by speed and length of stay).
   - It is proposed: to use hydraulic constructions and variability (dynamism) to improve the flipper design. One can form an enclosed longitudinal hollow in the elastic flipper material. This is filled with an fluid whose pressure can be adjusted using a piston valve. High pressure makes the flipper blade rigid. This can be adjusted to optimize for current swimming (wind) conditions.

6. **Flexible wing - blade.**

This repeatable process overcomes common TRIZ deployment challenges by showing a workflow and methodology for how to get started working on a problem with TRIZ, how to compliment TRIZ with Value Methodologies for problem identification, and how to leverage internal and external knowledge sources to accelerate concept identification.
About the Authors:

Isak Bukhman, TRIZ Master, Chief Methodology Specialist, Invention Machine

Isak has spent 7 years at IMC and currently serves as their Chief Methodology Specialist. He is a TRIZ Master, Value Methodology (VM), and 6Sigma certified specialist with more than 20-year practice in the product/process development and manufacturing areas. He guided development of innovation projects for several world leading companies such as Philips, Mattel/Fisher-Price, Microsoft, Shell, Samsung, LG, POSCO, Masco, Medtronic, Xinetics, Henkel, etc.

He also directed a team of more than 100 scientists, experts, developers, and animators that designed and developed about 8000 detailed description and running movies of scientific and engineering effects. He created the unique functional/parametric classification system for the scientific/engineering knowledge database and developed the Control & Connect Modes for new knowledge creation by linking effects.

He has delivered numerous basic and advanced seminars (some together with Genrich Altshuller), and educated and trained more than 600 Managers, Engineers, and Researchers in TRIZ/Value Methodology, and in Product/Process Evolution and Development.

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Stephen Brown, Vice President Strategic Marketing, Invention Machine Corp.,

Steve is responsible for product marketing activities including the positioning and future evolution of the company's market strategy. Prior to Invention Machine, he spent 10 years at Vality Technology, the industry's leading supplier of data quality software for the ERP, CRM, and business intelligence markets where he served as Vice President of Product Strategy until its acquisition by Ascential Software in April 2002. At Ascential, he served as Executive Director, leading Product Management and Marketing functions for Ascential's suite of data-integration products. Previously Steve had served 20 years in technology management and development capacities at Legent Corporation, Cullinet Software and Honeywell. He is a graduate of Harvard University.

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A Repeatable Process for Improving Any Technical System.

by

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Project Roadmap

System Analysis and Pre-Problems Statement

- Pre-Problems Selection for further solving
- Trimming
- System Function Analysis
- Information gathering
- Project Description

Existing System Improvement

WIND TURBINE

Problems Solving

- Diagrams of Typical Conflicts
- ARIZ-85B - Part 1
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  - Result: statement (model) of the problem
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- Inventive Principles
- System Modification Patterns
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- Patent Collections

Informational fund

Concepts Evaluation & Selection

Project Report Generation

Concepts Development & Implementation
We have selected Three-Blades Turbine as a base Turbine design for our research project.

Three-Blades Turbine are most common, sometimes it could as a Danish Concept. These three-bladed wind turbines are operated "upwind," with the blades facing into the wind.

Initial Situation

Wind turbine works the opposite of a fan. Instead of using electricity to make wind, a turbine uses wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. The electricity is sent through transmission and distribution lines to a substation, then on to homes, business and schools.

http://www.nrel.gov/wind/animation.html
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Concepts Evaluation & Selection

Project Report Generation

Concepts Development & Implementation
Component Structure of the Wind turbine

1. Blades
2. Rotor
3. Pitch
4. Brake
5. Low-speed shaft
6. Gear box
7. Generator
8. Controller
9. Anemometer
10. Wind Vane
11. Nacelle
12. High-speed shaft
13. Yaw drive
14. Yaw motor
15. Tower

Hub
Wind Turbine Components

Anemometer:
Measures the wind speed and transmits wind speed data to the controller. These are attached to the back of the nacelle. A 3-cup anemometer spins to measure the wind speed.

(Rotor) Blades:
Wind turbine blades act similar to an airplane's wing or a boat's sail. When air travels over the curved blade, a low-pressure area is created on the concave side of the blade (referred to as Bernoulli's effect) creating pressure. This pressure pushes against the blade, causing the rotational mechanical energy that drives the low speed shaft connected to the hub.
The rotor blades are the elements of the turbine that capture the wind energy and covert it into a rotational form. The profile and shape of the blade is designed for maximum efficiency and minimum noise. The turbine blades are made of fiberglass. Using stronger and more lightweight materials has allowed manufacturers to create larger blades, increasing the capacity of the turbines.
Wind Turbine Components (con.)

Brake:
A disc brake which can be applied mechanically, electrically, or hydraulically to stop the rotor in emergencies. The **mechanical brake** is a physical brake, similar to a disc brake on the wheel of a car, connected to the high-speed shaft. It is used for servicing the equipment to ensure that no components start to rotate, endangering the repair worker. This is used to stop the blades rotating in gale force winds or for maintenance purposes. It is hydraulically operated using the same principles as found in a car's disc brakes.

(Electronic) Controller:
The controller starts up the machine at wind speeds of about 8 to 16 miles per hour (mph) and shuts off the machine at about 65 mph. Turbines cannot operate at wind speeds above about 65 mph because their generators could overheat. The controller is a computer system that monitors and controls various aspects of the turbine. It has the ability to shut down the turbine if a fault occurs. Continuously monitors the condition of the wind turbine. Controls pitch and yaw mechanisms. In case of any malfunction (e.g., overheating of the gearbox or the generator), it automatically stops the wind turbine and may also be designed to signal the turbine operator's computer via a modem link.
Cooling system:

The cooling system is used to ensure that the components do not overheat and cause damage to themselves or any other component. A typical cooling system is either an electrical fan or a radiator system.

Gear box:

Gears connect the low-speed shaft to the high-speed shaft and increase (transform) the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1200 to 1500 rpm and drives the generator. Connects to the low-speed shaft and turns the high-speed shaft at a ratio several times (approximately 50 for a 600 kW turbine) faster than the low-speed shaft. Almost all wind turbines (except, Variable Speed Gearless Wind Turbine) contain gearboxes, which convert the slow rotation of the shaft into the high speed required to generate electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes.
Wind Turbine Components (con.)

Generator:
The generator is connected to the high-speed shaft and is the component of the system that converts the rotational energy of the shaft into an electrical output. Usually an off-the-shelf induction generator that produces 60-cycle AC electricity. The generator (3-phase, 690 volt) is driven by the high-speed shaft and also turns at 1,500 rpm, supplying electricity through a low voltage transformer to a high voltage transmission transformer and into Country Energy's distribution grid. In recent years, wind power has become very competitive in electrical cost production due to increased efficiencies and the increased size of the generators, with typical outputs over 500kW for newer, utility-scale systems. Usually an induction generator or asynchronous generator with a maximum electric power of 500 to 1,500 kilowatts (kW) on a modern wind turbine.

High-speed shaft:
Drives the electrical generator by rotating at approximately 1,500 revolutions per minute (RPM).
Wind Turbine Components (con.)

Hub:
For propeller-driven turbines hub is the connection point for the rotor blades and the low speed shaft. Hub captures the wind and transfers its power to the rotor. Attaches the rotor to the low-speed shaft of the wind turbine. The hub is made of cast iron and connects the turbine's blades to the main shaft. When the wind blows, the blades and hub rotate at 28 revolutions per minute (rpm). The hub and blades together weigh 8.5 tones.

Low-speed shaft:
The rotor turns the low-speed shaft at about 30 to 60 rotations per minute. Connects the rotor hub to the gearbox. Low-speed shaft is connected with large gear (ones is a component of the gearbox) and transmits rotation to it.
Nacelle:
The case or housing (from steel and/or fiberglass...), which is mounted on the tower and includes (encapsulates, supports, protects, covers) the gear box, low- and high-speed shafts, electrical generator, yaw system, hydraulics, controller, and brake. The nacelle can move through 360° and is turned into the wind using "yaw" motors that are controlled by the wind vane. The nacelle and equipment weigh 19 tones.

Pitch (Mechanism):
Blades are turned, or pitched, out of the wind to keep the rotor from turning in winds that are too high or too low to produce electricity. Vestas company -> Pitch control is achieved by feathering the blades.

Rotor:
The blades and the hub together are called the rotor and it rotates a low-speed shaft.
Wind Turbine Components (con.)

**Tower:**
Because wind speed increases with height, taller towers (it is advantageous) enable turbines to capture more energy and generate more electricity. The tower is used to support (carries) the nacelle and rotor blades (rotor).

**Wind vane:**
Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind. Measures the direction of the wind while sending signals to the controller to start or stop the turbine.

**Yaw drive:**
Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. These are controlled by the information from the wind vane and ensure that the nacelle is always facing into the wind. Downwind turbines don't require a yaw drive, the wind blows the rotor downwind.

**Yaw motor:**
Powers the yaw drive.
Trends of the R&D efforts that have contributed to current utility-scale turbine technology

- Improvements in the aerodynamics of wind turbine blades, resulting in higher capacity factors and an increase in the watts per square meter of swept area performance factor.

- Development of variable speed generators to improve conversion of wind power to electricity over a range of wind speeds.

- Development of gearless turbines that reduce the ongoing operating cost of the turbine.

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Environmental benefits of the 10 % target would be enormous – savings of 69 million tones of CO2 in 2005, 267 millions tons in 2010 and 1780 million tones in 2020.
Wind Turbine -> Functional Model
Advanced Function Properties Definition

Blades (three)

push (rotate)
capture

wind (wind energy)
Function Parameter Definition

Select or enter an action. Then, enter one or more parameters it changes in the **Blades (three)**.

**Actions**
- capture
- **push (rotate)**
- +

**Parameters**
- ✓ torque
Specify the actual and the required values of defined Parameter
(Qualitative mode)

Choose the function type performed by the selected action:
- Useful
- Harmful

Discrepancy = |Actual - Required| = 8.0

Purpose of this value:

Why is the required value necessary?

Actual value:

Required value:

Select or enter an action. Then, enter one or more parameters it changes in the Blades (three).

Actions
- capture
- push (rotate)

Parameters
-  
-  
-  

Value
- Qualitative
- Quantitative

Specify the actual and the required values:

Actual value: 30

Required value: 70
Specify the actual and the required values of defined Parameter (Quantitative mode)

- Actual value: 2000 N·m
- Required value: 4000 ± deviation N·m

Why is the required value necessary?

- to increase effectiveness of blades

Discrepancy = \frac{|Actual - Required|}{Accepted Deviation} = 5.0
Create two graphs of dependence between defined parameter and one of the related parameter -> actual and required.
Model Data -> Device Diagnostic -> Component Parameters and rating
Functional Analysis & Trimming -> Strategy Selection
Functional Analysis & Trimming -> Your Own Strategy Creation

Define Diagnostic Criteria

Criteria name: Perfection

Formula:

\[ V = \frac{3^*K_1}{P + 2^*C} \]

Parameters:

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Symbol</th>
<th>Best Value</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function Rank (F)</td>
<td>F</td>
<td>Maximum</td>
<td>1</td>
</tr>
<tr>
<td>Problem Rank (P)</td>
<td>P</td>
<td>Minimum</td>
<td>1</td>
</tr>
<tr>
<td>Cost (C)</td>
<td>C</td>
<td>Minimum</td>
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<tr>
<td>reliability</td>
<td>K1</td>
<td>Maximum</td>
<td>3</td>
</tr>
</tbody>
</table>

Help  OK  Cancel
**Project Roadmap**

**System Analysis and Pre-Problems Statement**

- Pre-Problems Selection for further solving
- Trimming
- System Function Analysis
- Information gathering
- Project Description

**Problems Solving**

- Diagrams of Typical Conflicts
- ARIZ-85B - Part 1
  - INITIAL SITUATION ANALYSIS – Selection of Mini-Problem
  - Result: statement (model) of the problem
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**Result: list of resources of space, time, substances, and fields**

**ARIZ-85B - Part 2**

- PROBLEM MODEL ANALYSIS
- Result: direction toward the most potent answer

**ARIZ-85B - Part 3**

- DETERMINATION of IFR (Ideal Final Result) and Physical Contradiction
- Result: list of resources of space, time, substances, and fields

**Project Generation**

- Concepts Evaluation & Selection

**Existing System Improvement**

- WIND TURBINE

**Concepts Development & Implementation**
Design Simplification Strategy - Trimming Method
Radical product/process changes

Benefits:

► Improves product/process by eliminating low value (problematic) components and redistribution their useful functions between other components.

► Trimming Method simplifies and reduces the cost of user product/process, while preserving the essential functionality.

► The design variants that results from Trimming will generate different problem statements, if solved, can lead to highly innovative solutions.
First page of the Trimming Process

Diagram showing the components and connections of the Trimming Process:
- Hub
- Nacelle
- Blades (three)
- AC Generator
- Brake
- Yaw drive
- Yaw motor
- Controller (Electronic)
- AC Electricity
- Operator computer
- Wind (wind energy)
- Tower
- Pitch (Mechanism)

Diagnostic Criteria
- Maximum Value
- V = F * F
- P + C

Component parameters and rating:

<table>
<thead>
<tr>
<th>Components</th>
<th>Function Rank (F)</th>
<th>Problem Rank (P)</th>
<th>Cost (C)</th>
<th>Rating</th>
</tr>
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<tbody>
<tr>
<td>Tower</td>
<td>1.40</td>
<td>0.00</td>
<td>700.00</td>
<td>0.19</td>
</tr>
<tr>
<td>Pitch (Mechanism)</td>
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<td>8.36</td>
<td>20.00</td>
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<tr>
<td>Yaw motor</td>
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<td>0.00</td>
<td>150.00</td>
<td>0.40</td>
</tr>
<tr>
<td>Blades (three)</td>
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<td>500.00</td>
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<tr>
<td>Gear box</td>
<td>3.49</td>
<td>9.18</td>
<td>25.00</td>
<td>1.28</td>
</tr>
</tbody>
</table>
“Low-speed shaft” trimming

Trimming: Eliminate problematic Components by reassigning their functions

Components:
- wind speed data
- wind direction data
- Low-speed shaft
- Brake
- Hub
- AC Generator
- Yaw drive
- Cooling system

Output actions:

Eliminate or simplify the Low-speed shaft Component by:
- Reassigning the function connect Hub to the
- Eliminating the Component Hub
- Eliminating the function connect Hub
- Reassigning the function connect Hub to
- Do not change the function connect Hub
1. Low-speed shaft, Gear box, High speed shaft, Wind wane, Wind direction data, Pitch (mechanism) were trimmed.
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Concepts Development & Implementation

Project Report Generation
We have selected one problem (pre-problem) from 20 ones for the next stage of the project:

The value of the torque parameter, which describes the effect of the action push (rotate) by the wind (wind energy) on the Blades (three), is 2000 Nm. Required value of this parameter is 4000 Nm to provide to increase efficiency of blades.

How to increase the torque of the Blade?
Project Roadmap

### System Analysis and Pre- Problems Statement
- Pre-Problems Selection for further solving
- Trimming
- System Function Analysis
- Information gathering
- Project Description

### Problems Solving
- Diagrams of Typical Conflicts
- ARIZ-85B - Part 1
  - INITIAL SITUATION ANALYSIS – Selection of Mini-Problem
  - Result: statement (model) of the problem
- ARIZ-85B - Part 2
  - PROBLEM MODEL ANALYSIS
  - Result: list of resources of space, time, substances, and fields
- ARIZ-85B - Part 3
  - DETERMINATION of IFR (Ideal Final Result) and Physical Contradiction
  - Result: direction toward the most potent answer

- TRIZ - System of Standards
  - Inventive Principles
  - System Modification Patterns
- Informational fund
  - Scientific Effects Library
  - Patent Collections

### Existing System Improvement
- WIND TURBINE

### Concepts Development & Implementation
- Project Report Generation
- Concepts Evaluation & Selection
Algorithm for Inventive Problem Solving

Initial situation/pre-problem statement:

Wind flow rotates wind turbine blades/rotor (creates torque).

Three parameters determine torque of the rotor: blade length, blade concave surface area, and wind flow pressure on the blade concave surface.

Low speed of wind flow decreases rotor torque, what decreases rotor rotational speed.

It is necessary to prevent rotor rotational speed decreasing.

Note: speed of wind flow could not be changed – it is a supersystem element.

1.1. Write down conditions of a mini-problem (without special terms) as follows:

The technical system (purpose/main function of the system/product) includes (list main parts of the system).

*The technical system to rotate rotor includes: wind flow, blades, and rotor.*

Under minimal changes in the system it is required: (specify a result which should be obtained).

*Under minimal changes in the system it is required: to prevent rotor rotational speed decreasing under low wind flow speed.*
Algorithm for Inventive Problem Solving – Part 1.2.

1.2. Selection of the conflicting pair:

Product (s): *rotor (high rotational speed, low rotational speed)*

Tools: *wind flow (low speed), blade (large surface area, small surface area)*
1.3. Formulate Technical Contractions TC 1 and TC 2 using a conflicting pair and create their diagrams using the Diagrams of Typical Conflicts in Table 1.

A. Technical contradiction 1 – TC 1: (identify)

**TC 1: if there is a blade with a large surface area, the rotor rotational speed is high [1], but blade weight [2] and length [3] are increased.**

B. Select/create diagram of **TC 1** using Table 1
Algorithm for Inventive Problem Solving – Part 1.3.

C. Technical contradiction 2 – TC 2: (identify)

**TC 2:** if there is a blade with a small surface area, the blade weight [2] and length [3] are normal, but rotor rotational speed is low [1].

D. Select/create diagram of TC 2 using Table 1
1.4. Select one conflict diagram from the two technical contradictions, (TC1 and TC2), that provides the best accomplishment of the main production process (the main function of the technical system specified in conditions of the problem).

The main function of the system is *to rotate rotor with high rotational speed*. So, *TC1* should be selected: in this case *a blade with a large surface area rotates rotor with high rotational speed*.

\[ \text{TC1} \]
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Concepts Evaluation & Selection
- Project Report Generation
- Concepts Development & Implementation
First Technical Contradiction
-> Recommendation # 15 – Dynamic Parts

**Problem:**
I want to increase rotor rotational speed by increasing blade surface area, which leads to the problem of large length of the blade.

**Solution:** Dynamic parts
- Allow (or design) the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition.
- Divide an object into parts capable of movement relative to each other.
- If an object (or process) is rigid or inflexible, make it movable or adaptable.
Example: Variable-rigidity flippers

Different rigidity is required in swimming flippers under different water conditions (governed by speed and length of stay). Can an adaptive flipper be designed?

It is proposed to use the principles of flexible shells, hydraulic constructions and variability (dynamism) to improve the flipper design. One can form an enclosed longitudinal hollow in the elastic flipper material. This is filled with a non-compressible fluid whose pressure can be adjusted (on the shore or underwater) using a piston valve. High pressure makes the flipper blade rigid. This can be adjusted to optimize for current swimming conditions.

SU A.c. N 317 390

You may increase rotor rotational speed by applying principle "15 - Dynamic parts" by analogy of example "Variable-rigidity flippers".

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Second Technical Contradiction

-> Recommendation # 29 – Pneumatics and Hydraulics

<table>
<thead>
<tr>
<th>Problem:</th>
<th>I want to increase rotor rotational speed</th>
<th>Improving area of moving object</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>by increasing blade surface area</td>
<td></td>
</tr>
<tr>
<td></td>
<td>which leads to the problem</td>
<td>Worsening weight of moving object</td>
</tr>
<tr>
<td></td>
<td>large weight of the blade</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solution:</th>
<th>Pneumatics and hydraulics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- use gas and liquid parts in an object instead of solid parts (e.g. inflatable, liquid-filled, air cushioned, hydrostatic, hydro-reactive).</td>
</tr>
</tbody>
</table>

Technical Recommendations:

- 2 - Separation
- 17 - Dimensionality change
- 29 - Pneumatics and hydraulics
- 4 - Symmetry change

Make object's parts gaseous or liquid
You may increase rotor rotational speed by applying principle "29 - Pneumatics and hydraulics".

**Idea:** for better synchronization with wind speed (and maybe - wind direction) and blade shape control -> some parts of blade could be made by using "Pneumatics and hydraulics".
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Existing System Improvement

WIND TURBINE

Problems Solving

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Informational fund

Concepts Evaluation & Selection

Project Report Generation

Concepts Development & Implementation
Query: How does surface increase area?

5 most relevant result(s).

<table>
<thead>
<tr>
<th>Most relevant:</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. One-sided surface increases area</td>
<td>Most relevant:</td>
</tr>
<tr>
<td>One-sided surface increases area (Moebius band)</td>
<td>- sided surface (1)</td>
</tr>
<tr>
<td>- 1 Most relevant and 6 Related result(s) from this document</td>
<td>- area (1)</td>
</tr>
<tr>
<td>2. Compressing the contacting surfaces of two objects increases the area of contact.</td>
<td>- contacting surface of... (1)</td>
</tr>
<tr>
<td>Compression increases contact area between objects</td>
<td>- area of contact (1)</td>
</tr>
<tr>
<td>- 1 Most relevant and 18 Related result(s) from this document</td>
<td>- emitting surface area (1)</td>
</tr>
<tr>
<td>3. Increasing the surface roughness of the solid increases its emitting surface area.</td>
<td>- surface roughness of... (1)</td>
</tr>
<tr>
<td>Thermal radiation dependence on surface roughness</td>
<td>- droplet surface contact... (1)</td>
</tr>
<tr>
<td>- 1 Most relevant and 5 Related result(s) from this document</td>
<td>- Increased roughness of... (1)</td>
</tr>
<tr>
<td></td>
<td>- pore surface area (1)</td>
</tr>
<tr>
<td></td>
<td>- catalyst surface area (1)</td>
</tr>
<tr>
<td></td>
<td>Related:</td>
</tr>
<tr>
<td></td>
<td>- surface area (33)</td>
</tr>
<tr>
<td></td>
<td>- contact area (30)</td>
</tr>
</tbody>
</table>
Example:
One-sided surface increases area (Mobius band)

The Mobius band is a closed one-sided surface. Turning one end of a rectangle by 180° and attaching it to the other end produces a Mobius band. Its area is twice the area of the original rectangle. An object moving along the Mobius band surface parallel to its edge will return to its starting point.

Advantages
1. A Mobius band is used in devices that require a one-sided surface.
2. The Mobius band has an infinite surface.
GFIN Scientific Effects Module

Example: Motor blade in form of Mobius strip

In windmills, propellers are used to impart rotation to a shaft. The propeller blades have a complicated surface; they are difficult to fabricate.

Solution
A blade is fixed on a shaft by means of spokes. The blade is made of elastic material and has the Mobius strip form.

The blade is blown over by an air stream. The blade surface is located at an angle to the air stream direction. Due to this, an aerodynamic force occurs. It rotates the blade and the shaft.

The blade is fabricated from elastic material as a strip. No complicated surface contouring is required for this purpose.

Advantages
1. The propeller blade in the Mobius strip form is simple in design.
2. The blade in the Mobius strip form is easy to manufacture.
3. The blade has a low aerodynamic...
Query: How to increase the torque of the blades?

1. Rotation direction and guiding the airflow from the path thus formed to the rear face of the blade body, so as to generate lift on the leading edge auxiliary vane and increases a rotating torque of the turbine blade; and the blade body...
   US-20030123973 A1 Propeller type windmill for power generation
   6 Most relevant and 82 Related result(s) from this document

2. Vane frontwardly in the rotational direction and guiding the airflow from the formed path thus formed to the rear face of the blade body, thereby generating lift on the leading edge auxiliary vane and increasing a rotating torque of the turbine blade.
   US-6732595 B2 Propeller type windmill for power generation
   6 Most relevant and 82 Related result(s) from this document

3. Rotation direction and guiding the airflow from the path thus formed to the rear face of the blade body, so as to generate lift on the leading edge auxiliary vane and increases a rotating torque of the turbine blade; and the blade body...
   EP-1375911 A1 PROPELLER TYPE WINDMILL FOR POWER GENERATION
   5 Most relevant and 84 Related result(s) from this document

4. The invention is to solve the problems of the prior arts, and it is an object thereof to present a washing machine capable of increasing the rotating torque of the agitating blades without increasing the torque of the drive motor, and capable of...
   US-20020184928 A1 Washing machine
   3 Most relevant and 111 Related result(s) from this document

5. The invention is to solve the problems of the prior arts, and it is an object thereof to present a washing machine capable of increasing the rotating torque of the agitating blades without increasing the torque of the drive motor, and capable of...
Propeller type windmill for power generation

This invention relates to a propeller-type wind turbine used in wind-powered electrical generation.

The invention of claim 6 is the structure according to claim 5, characterized in that the blade body of each turbine blade includes a rear auxiliary vane provided at the trailing edge portion and being capable of extending and retracting rearward in the rotation direction, and a rear auxiliary vane extension-and-retraction unit for protruding the rear auxiliary vane rearward so as to increase a vane arc length.

With this structure, the pitch changing guide member allows the pitch of the vane bodies to continuous with that of the tip auxiliary blades, forming a vane of a better performance.

Furthermore, because the pitch addition means 11 is provided to the extension-and-retraction guide unit 9, when the tip auxiliary blades 6 are extended from inside the blade bodies 4, a specific rotational displacement is imparted, allowing a continuous pitch to be formed from the blade bodies 4 to the tip auxiliary blades 6, so operation is more efficient.
An object of the invention is to provide an air turbine headpiece in which a rotor can be efficiently rotated at high torque, in connection with a nozzle opening for injecting air to a turbine blade portion.

<table>
<thead>
<tr>
<th>Publication Number</th>
<th>US-5902108</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Air turbine handpiece</td>
</tr>
<tr>
<td>Application</td>
<td>The present invention relates to an air turbine handpiece which can be usefully applied to medical treatment or the like.</td>
</tr>
<tr>
<td>Task</td>
<td>An object of the invention is to provide an air turbine handpiece in which a rotor can be efficiently rotated at high torque, in connection with a nozzle opening for injecting air to a turbine blade portion.</td>
</tr>
<tr>
<td>Method</td>
<td>In a twenty-third aspect of the invention, the head portion comprises a head body which forms the chamber, an inner housing member is attached to a interior of the chamber of the head body, a sleeve member is attached to an outer peripheral surface of the inner housing member, and an auxiliary air flow path which guides air from the first turbine blade portion to the second turbine blade portion is formed by the sleeve member and the inner housing member.</td>
</tr>
<tr>
<td>Features</td>
<td>According to the twenty-sixth aspect of the invention, the rotor having the first and second turbine blade portions can be produced relatively easily and economically.</td>
</tr>
</tbody>
</table>
1.5. Reinforce (intensify) a conflict, specifying a limit state (action) of elements (parts).

Let's assume that instead of "a large surface area" "a very large surface area" is specified in TC 1.
1.6. Write down a specified problem model:

A. Conflicting pair

B. **Blade with a very large surface area and a rotor with a high rotational speed.**

B. Reinforced (intensified) formulation of a conflict

B. **Blade with a very large surface area increases the rotational speed of rotor [1], but blade weight [2] and length [3] are increased.**

C. It is required to find x-element, which solves a conflict of the selected TC (to preserve, to eliminate, to improve, to provide, etc.).

C. **It is required to find x-element, which preserves the ability of the blade with a very large surface area to rotate rotor with a high rotational speed would not create a large weight and length of blade.**
Project Roadmap

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Existing System Improvement
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Concepts Evaluation & Selection

- Scientific Effects Library
- Patent Collections
- Informational fund

Concepts Development & Implementation

Project Report Generation
1.7. Check possibility of using of the System of Standards to solve the problem model. Transition from functional model to the Su-Field model.
1.2.2. Harmful interaction (function) removal by modification of the existing substances.

If useful and harmful actions are linked between two substances in a S-Field (direct contact of substances is not necessary to preserve and using of foreign substance is prohibited or to no purpose),

the problem could be solved by introduction of a modified third substance (modification of any existing substances, or their combinations) between those two substances.

**Note:** it is clear -> the given standard orients us to use available substance-field recourses.
GFIM System Modification Pattern Module – Standard 1.2.2.

Solution:

- Blade large surface
  - create
  - neutralize
- Heavy blade
  - contains
- gas

Problem: How to neutralize action create from Blade large surface to Heavy blade?

Solution:

Try to neutralize the action create by introducing gas into the Heavy blade.

New Substance

Choose the type of new substance below:

- gas
- States of substances:
  - vacuum
  - field
  - plasma
  - gas
GFIN System Modification Pattern Module – Standard 1.2.2
GFIN Problem & Solution Manager

**Problems & Solutions:**
- Design Scenarios:
  - Wind Turbine, scenario #1
    - Combining several various objects with long blade into a common system...
    - Segmenting the long blade into several parts.
  - ARIZ - 3.6 → large surface area
    - Fully coordinating the action create between the blade parts and the...
    - Introducing bi-metal into the blade parts.
    - Introducing high thermal expansion substance into the blade parts.
  - ARIZ 1.7 → Surface area
    - Introducing gas into the heavy blade.
    - Introducing body with pores and capillaries around the heavy blade.
    - Introducing void into the heavy blade.
  - ARIZ 3.3:3.4. → width should be small and should be large
    - Separation in time.

**Problem description:**
- Name: ARIZ 1.7. → Surface area
- I want to: increase blade surface area
- It increases weight of the blade

**Solution:**
- Name: Introducing gas into the Heavy blade.

You may increase blade surface area by applying the concept "introducing gas into the heavy blade". Standard 1.2.2.

**Note:** Patterns/Standards suggest us to use partially inflatable blade
GFIN System Modification Pattern Module – Standard 1.2.2.

Solution:

Blade large surface... → create → Heavy blade
neutralize
surrounded by

body with pores and capillaries

Problem: How to neutralize action create from Blade large surface to Heavy blade?

Try to neutralize the action create by introducing body with pores and capillaries around the Heavy blade.

Modified Substance

Choose the type of modified substance below:

- body with pores and capillaries

Object 1 → Object 2

Two objects → Internal additive → External additive

- Phase transitions of the 1st kind
- Phase transitions of the 2nd kind
- Change of physical parameters
- Change of chemical parameters
- Change of motion parameters
- Formation of mixtures
- Structurization
  - formation of pores and capillaries
  - segmentation to particles
GFIN System Modification Pattern Module – Standard 1.2.2
GFIN Problem & Solution Manager

**Problems & Solutions:**
- **Design Scenarios:**
  - Wind Turbine, scenario #1
    - Combining several various objects with long blade into a common system...
    - Segments the long blade into several parts.
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    - Introducing gas into the Heavy blade.
    - Introducing body with pores and capillaries around the Heavy blade.
    - Introducing void into the heavy blade.
  - ARIZ 3.3.3.4. -> width should be small and should be large
    - Separating "y" in time.

**Problem description:**
- **Name:** ARIZ 1.7. -> Surface area
- **I want to:** increase blade surface area
- **It increases weight of the blade**

**Solution:**
- **Name:** Introducing body with pores and capillaries around the Heavy blade.

You may increase blade surface area by applying the concept **"Introducing body with pores and capillaries around the Heavy blade"** Standard 1.2.2.

Patterns/Standards suggest us to use for blade design pores and capillaries.
2.2.4. Transition to Dynamic (flexible) S-Fields Models

Efficiency of the S-Field model could be improved by transition to dynamic (more flexible) structure of the system.

Explanations:
Transition to dynamic of $S_1$ (tool) usually starts with its breaking into two jointed parts. Further, the dynamism proceeds along the following line: joint $\rightarrow$ many joints $\rightarrow$ flexible $S_1$.

Note: in our case -> blade, parts of the blade, and surfaces of the blade should be flexible in the shape, in the parameters, in…
Standard 2.2.4. -> Concept

Flexible wing - blade

http://i.timeinc.net/popsy/images/space/space1003wing_A5_197.jpg
Metal muscles made of alloys that remember shapes are connected to evenly spaced vertebral column and shrink and expand as much as 8 percent as they’re alternately heated and cooled, causing the 3-foot sub’s sectioned hull (AND OUR BLADE AS WELL) to bend and flex.

Efficiency of bi- and poly-systems systems could be improved via development of differences between their components (system transition 1-b):

- similar components with similar parameters (set of similar pencils);
- components with shifted parameters (set of color pencils);
- different components (case of drawing instruments);
- inverse combinations like “component – anti-component (pencil and eraser).

Note: in our case -> blade should be divided into different parts with shifted or different parameters
Standard 3.1.3. -> Concept

Doubled propeller – Doubled blades

- The propeller is the contra rotating with a diameter of 4.5 m (14 ft 9 in).
- It has blades made of advanced composites and pronounced scimitar-like curvature on the leading-edge. It offers increased efficiency under high-speed cruise, and improved acoustics.
- There are six blades in the front propeller and eight in the rear, the latter absorbing most of the power and providing most of the thrust.

Standard 3.1.3. -> Concept

Efficient propeller – Efficient blade

A propeller produces a propulsion that drives an airborne vehicle.

**Disadvantage:** This causes an air stream to be driven back, causing high turbulence. This decreases the propulsion.

It is proposed to mount two stationary blades directly behind the propeller. The two stationary blades act as an air stream stabilizer. The propeller efficiency increases by 30% as a result of the air stream ordering.
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Informational fund

Concepts Evaluation & Selection

Project Generation

Concepts Development & Implementation
Algorithm for Inventive Problem Solving – Part 2.1.

2.1. Conflict zone (CZ) determination.

*Blade body*

15 large wind turbines, each capable of generating 1.8 megawatts can provide enough electricity to supply 3,329 homes.

[Image: http://www.communityenergy.biz/images/gllry_blade_event2.jpg]
2.2. Operation Time (OT) determination.

*OT is a $T_2$ (conflicting time -> time of wind flow low speed)*

**Note:**
In our case we don’t have pre-conflicting time -> $T_1$ and post-conflicting time $T_3$ because speed of the wind flow is always low for our situation and could not be changed – it is a supersystem component.
Algorithm for Inventive Problem Solving – Part 2.3.

2.3. Determine substance-field resources (SFR).

1. **Internal-System SFR:**
   - **Substances:**
     - geometry elements of the blade;
     - blade;
     - rotor;
   - **Fields:**
     - wind flow pressure on the blade surface;
     - centripetal forces;
   - **Parameters:**
     - weight of the blade;
     - length of the blade;
     - width of the blade;
     - rotational speed of the rotor;
     - area of the blade surface;
     - torque of the blade;
     - specific weight of blade;
     - shape of the blade;
     - blade center of gravity;
     - distance between rotor and earth surface;

2. **External-System Resources**
   - **Substances:**
     - air;
     - drops of rain;
     - snow;
   - **Fields:**
     - wind flow;
     - sun energy;
     - gravity;
   - **Parameters:**
     - speed of the wind flow;
     - direction of the wind flow;
     - wind flow pressure;
     - temperature of the air;
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WIND TURBINE

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Concepts Evaluation & Selection

Concepts Development & Implementation

Project Generation

Value Engineering
TRIZ modules/parts
Algorithm for Inventive Problem Solving – Part 3.1.

3.1. Write down a formulation of IFR-1.

\( X\)-element while not complicating the system and causing harmful phenomena eliminates large weight and large length of blade increasing during OT within CZ preserving the ability of the blade with a very large surface area to rotate rotor with a high rotational speed.

![Diagram of X-element and conflicts](image)

**Operation Time - OT**

- **T2**
  - Time of wind flow
  - Low speed

**CONFLICT**

- **Rotor** - High rotational speed
- **Blade** - Large weight
- **Blade** - Large length
3.2. Reinforce (intensify) a formulation of IFR-1 with additional requirements: it must not introduce new substances and fields into the system - use SFR.

**Variant # 1**

X-element **Blade center of gravity replacement** while not complicating the system and causing harmful phenomena eliminates large weight and large length of blade increasing during OT within CZ preserving the ability of the blade with a very large surface area to rotate rotor with a high rotational speed.

![Diagram of Blade center of gravity replacement](image)

**Algorithm for Inventive Problem Solving – Part 3.2.**

- **Rotor** - High rotational speed
- **Blade** - Large weight
- **Blade** - Large length

**Operation Time - OT**

- $T_2$
  - Time of wind flow
  - Low speed

**CONFLICT**

Beginning of conflict | Ending of conflict

---

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Algorithm for Inventive Problem Solving – Part 3.2.

3.2. Reinforce (intensify) a formulation of IFR-1 with additional requirements: it must not introduce new substances and fields into the system - use SFR.

**Variant # 2**

X-element Area of the blade surface increasing while not complicating the system and causing harmful phenomena eliminates large weight and large length of blade increasing during OT within CZ preserving the ability of the blade with a very large surface area to rotate rotor with a high rotational speed.

**Algorithm for Inventive Problem Solving – Part 3.2.**

Area of the blade surface increasing

- **Rotor - High rotational speed**
- **Blade - Large weight**
- **Blade - Large length**

**Operation Time - OT**

- **T₂**
  - Time of wind flow
  - low speed

**CONFLICT**

Beginning of conflict

Ending of conflict
3.3. Write down a formulation of a PC on a macro-level (variant # 2)

*Blade (CZ) during OT should be with a very large surface area to rotate rotor with a high rotational speed and should be with a small surface area to prevent blade overweight and over length.*
Project Roadmap

System Analysis and Pre-Problems Statement

- Pre-Problems Selection for further solving
- Trimming
- System Function Analysis
- Information gathering
- Project Description

Existing System Improvement
- WIND TURBINE

Problems Solving

- Diagrams of Typical Conflicts
- ARIZ-85B - Part 1
  - INITIAL SITUATION ANALYSIS – Selection of Mini-Problem
  - Result: statement (model) of the problem

- ARIZ-85B - Part 2
  - PROBLEM MODEL ANALYSIS
    - Result: list of resources of space, time, substances, and fields

- ARIZ-85B - Part 3
  - DETERMINATION of IFR (Ideal Final Result) and Physical Contradiction
    - Result: direction toward the most potent answer

- TRIZ - System of Standards
- Inventive Principles
- System Modification Patterns
- Scientific Effects Library
- Patent Collections

Informational fund

Concepts Evaluation & Selection

- Concepts Development & Implementation
- Project Report Generation
Query: flexible turbine blade

Selected Patent: US-4291235

1. Each flexible turbine blade 40 is attached to one end of a turbine spar 38 as shown and tethered to an adjacent spar by turbine blade tethers 42.
   US-5040948 Coaxial multi-turbine generator
   4 Most relevant and 120 Related result(s) from this document

2. Several wind turbine designs, such as those described in U.S. Pat. Nos. 4,352,629, 6,327,957 and 5,584,655 (all of which are incorporated herein by reference) describe highly flexible wind turbine blades.
   US-20040057828 A1 Wind turbine blade deflection control system
   2 Most relevant and 119 Related result(s) from this document

3. A water turbine, comprising: (a) a turbine rotor longitudinally extending between opposed ends of the rotor; and, (b) a plurality of relatively narrow, flexible elongated turbine blades extending outwardly from said rotor for communication with a water current, wherein: (i) said blades are...
   US-20040096310 A1 Apparatus and method for generating power from moving water
   1 Most relevant and 126 Related result(s) from this document

4. FIG. 17 is a perspective view showing a swash plate actuating linear potentiometers for flexible control of turbine blade angle of incidence.
   US-4491739 Airship-floated wind turbine
   1 Most relevant and 150 Related result(s) from this document

As the rotational speed of the turbine increases, a component of the centrifugal force acting on the out-of-plane weight applies a torsional force to the outer portion of the torsionally flexible turbine blades, thereby twisting the blades about their radial...
The turbine blade system comprises a plurality of torsionally flexible cambered sheet airfoil blades rigidly mounted to the same rotatable structure that supports and contains the permanent-magnet field elements. Specifically, it eliminates the need for shafts, gears, and other coupling devices between the turbine blade system and the electrical generating system. The effect of these features individually and in combination is to reduce the complexity of the wind turbine, the generating system, and their associated parts. As the rotational speed of the turbine increases, the pitch of the blades is automatically and continuously decreased so as to improve the aerodynamic efficiency at high tip speed ratios. A further advantage of the subject turbine/generator configuration is that the multiple-pole wound stators are fixed to the structure of the machine. This attenuates the vibrations induced into the system as the rotor yaws to accommodate a shifting wind direction.
Stator of Permanent Magnet Synchronous Generator directly connects Blades.

- Blades rotate directly Stator of Permanent Magnet Synchronous Generator. Permanent Magnet Synchronous Generator works good for variable blades rotational speed.
- Low-speed shaft, high-speed shaft, gear box, and other coupling devices between the turbine blade system and the electrical generating system are trimmed.

Trimming results & US Patent 4291235 -> Concept
Project Roadmap

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- Project Description

Problems Solving
- ARIZ-85B - Part 1
  INITIAL SITUATION
  ANALYSIS – Selection of Mini-Problem
  Result: statement (model) of the problem

- TRIZ - System of Standards

- ARIZ-85B - Part 2
  PROBLEM MODEL ANALYSIS
  Result: list of resources of space, time, substances, and fields

- ARIZ-85B - Part 3
  DETERMINATION of IFR (Ideal Final Result) and Physical Contradiction
  Result: direction toward the most potent answer

- Concepts Evaluation & Selection

Existing System Improvement
- WIND TURBINE

Concepts Development & Implementation
- Project Report Generation
## Concepts Evaluation & Selection

We have created 32 available solutions for farther development by using TRIZ, Value Engineering, and Informational Fund (Scientific Effects Library, Patent Collections, WEB based information), including:

<table>
<thead>
<tr>
<th>Solutions</th>
<th>From the Inventive Principles (Inventive Principles Module): 9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From the Effect Library (Effects Module): 2</td>
</tr>
<tr>
<td></td>
<td>From the System of Standards (System Modification Patterns Module): 12</td>
</tr>
<tr>
<td></td>
<td>From Patent Collections and WEB based information: 9</td>
</tr>
</tbody>
</table>

### From the Inventive Principles (Inventive Principles Module):
- Improve functionality solutions
- Simplify design solutions
  - 14 - Curvature increase
  - 15 - Dynamic parts
  - 4 - Symmetry change
  - 29 - Pneumatics and hydraulics
  - one-sided surface increases area (Moebius band)
  - Motor blade in form of Mobius strip
  - Summary: US-5902108 Air turbine handpiece
  - Summary: US-20030123973 A1 Propeller type windmill for power generation

### From the Effect Library (Effects Module):
- Introducing gas into the Heavy blade.
- Introducing body with pores and capillaries around the Heavy blade.
- Introducing void into the heavy blade.
- Making the long blade flexible.
- Making the long blade flexible.
- Creating protrusion on the long blade.
- Segmenting the long blade into several parts.
- Combining several various objects with short blade into a common system.
- Introducing one new object into the blade large surface area.
- Fully coordinating the action create between the blade parts and the large s
- Introducing bi-metal into the blade parts.
- Introducing High thermal expansion substance into the blade parts.
- Summary: US-5040948 Coaxial multi-turbine generator
Ranking Strategy Creation

Define Ranking Criteria

Criteria name: TRIZ and Value Engineering

Formula:

\[ K = 4^K1 + 6^K2 + 8^K3 \]

Parameters:

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Symbol</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation Cost</td>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>Implementation Time</td>
<td>T</td>
<td>1</td>
</tr>
<tr>
<td>level of ideality</td>
<td>K1</td>
<td>4</td>
</tr>
<tr>
<td>quantity of the produced electrical power</td>
<td>K2</td>
<td>6</td>
</tr>
<tr>
<td>technical feasibility</td>
<td>K3</td>
<td>8</td>
</tr>
<tr>
<td>new parameter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Solution Ranking

<table>
<thead>
<tr>
<th>Solutions</th>
<th>level of ideality ($K_1$)</th>
<th>quantity of the produced electrical power ($K_2$)</th>
<th>technical feasibility ($K_3$)</th>
<th>Rank Better</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introducing body with pores and capillaries around the blade</td>
<td>1.00</td>
<td>-1.00</td>
<td>1.00</td>
<td>-2.00</td>
</tr>
<tr>
<td>Making the long blade flexible.</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>18.00</td>
</tr>
<tr>
<td>Making the long blade flexible.</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>18.00</td>
</tr>
<tr>
<td>Segmenting the long blade into several parts.</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>18.00</td>
</tr>
<tr>
<td>Introducing one new object into the blade large surface.</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Summary: US-5040948 Coaxial multi-turbine generator</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Separation :: in time</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Introducing gas into the Heavy blade.</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Introducing void into the heavy blade.</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Combining several various objects with short blade in</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Introducing bi-metal into the blade parts</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>10.00</td>
</tr>
<tr>
<td>3 - Local quality</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>10.00</td>
</tr>
<tr>
<td>System transition :: to subsystem</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Introducing High thermal expansion substance into the blade</td>
<td>1.00</td>
<td>1.00</td>
<td>-1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>System transition :: to subsystem</td>
<td>1.00</td>
<td>1.00</td>
<td>-1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Separation :: in space</td>
<td>1.00</td>
<td>1.00</td>
<td>-1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Creating protrusion on the long blade</td>
<td>-5.00</td>
<td>-1.00</td>
<td>-5.00</td>
<td>-66.00</td>
</tr>
<tr>
<td>Fully coordinating the action create between the blade layers</td>
<td>5.00</td>
<td>1.00</td>
<td>-5.00</td>
<td>-14.00</td>
</tr>
</tbody>
</table>

## General Solutions

| Efficient propeller - Standard 3.1.3. and GFIN System                   | 1.00                        | 1.00                                        | 5.00                          | 50.00       |
| Some Concepts based on trimming scenario # 1 and                        | 5.00                        | 1.00                                        | 5.00                          | 66.00       |
| Doubled propeller - Standard 3.1.3. and GFIN System                    | 5.00                        | 1.00                                        | 5.00                          | 66.00       |
| Flexible wing - Standard 2.2.4. and GFIN System Model                  | 1.00                        | 1.00                                        | 0.00                          | 10.00       |
| Flexible hull - Standard 2.2.4. and GFIN System Model                  | 1.00                        | 1.00                                        | 0.00                          | 10.00       |
In total, 6 concepts were ranked as high level available solutions, having the ranking equal or higher than 10, including:

<table>
<thead>
<tr>
<th>#</th>
<th>Title of Concept</th>
<th>Ranking code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Stator of Permanent Magnet Synchronous Generator directly connects Blades</td>
<td>66</td>
</tr>
<tr>
<td>2.</td>
<td>Doubled propeller – Doubled blades</td>
<td>66</td>
</tr>
<tr>
<td>3.</td>
<td>Efficient propeller - Stream stabilizer</td>
<td>50</td>
</tr>
<tr>
<td>4.</td>
<td>Blade in form of Mobius strip</td>
<td>18</td>
</tr>
<tr>
<td>5.</td>
<td>Variable-rigidity flipper - blade</td>
<td>18</td>
</tr>
<tr>
<td>6.</td>
<td>Flexible Wing - Blade</td>
<td>10</td>
</tr>
</tbody>
</table>
Best Solutions

1. Stator of Permanent Magnet Synchronous Generator directly connects Blades.
   - Blades rotate directly Stator of Permanent Magnet Synchronous Generator. Permanent Magnet Synchronous Generator works good for variable blades rotational speed.
   - Low-speed shaft, high-speed shaft, gear box, and other coupling devices between the turbine blade system and the electrical generating system are trimmed.

- The propeller is the contra rotating with a diameter of 4.5 m (14 ft 9 in).
- It has blades made of advanced composites and pronounced scimitar-like curvature on the leading-edge. It offers increased efficiency under high-speed cruise, and improved acoustics.
- There are six blades in the front propeller and eight in the rear, the latter absorbing most of the power and providing most of the thrust.

Best Solutions


A propeller produces a propulsion that drives an airborne vehicle.

**Disadvantage:** This causes an air stream to be driven back, causing high turbulence. This decreases the propulsion.

*It is proposed* to mount two stationary blades directly behind the propeller. The two stationary blades act as an air stream stabilizer. The propeller efficiency increases by 30% as a result of the air stream ordering.
Best Solutions


A blade is fixed on a shaft by means of spokes. The blade is made of elastic material and has the Mobius strip form.

Advantages:
1. The propeller blade in the Mobius strip form is simple in design.
2. The blade in the Mobius strip form is easy to manufacture.
3. The blade has a low aerodynamic resistance and increases the windmill efficiency.
Best Solutions

5. Variable-rigidity flipper - blade.

Different rigidity is required in swimming flippers under different water conditions (governed by speed and length of stay).

**It is proposed:**

to use hydraulic constructions and variability (dynamism) to improve the flipper design. One can form an enclosed longitudinal hollow in the elastic flipper material. This is filled with a fluid whose pressure can be adjusted using a piston valve. High pressure makes the flipper blade rigid. This can be adjusted to optimize for current swimming (wind) conditions.
Best Solutions

6. Flexible wing - blade.

http://i.timeinc.net/popsci/images/space/space1003wing_A5_197.jpg
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Concepts Evaluation & Selection
- Concepts Development & Implementation
- Project Report Generation
This repeatable process overcomes common TRIZ deployment challenges by showing a workflow and methodology for how to get started working on a problem with TRIZ, how to complement TRIZ with Value Methodologies for problem identification, and how to leverage internal and external knowledge sources to accelerate concept identification.
Thank you very much

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