

Integrating Industrial Security into the TRIZ Design Method – SECUTRIZ Approach

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Abstract

Industrial security is a major concern for manufacturers, given the losses that can result from the presence or underestimation of hazards to which industrial installations are exposed. Taking this into account during the design phase remains a solution for overcoming or avoiding the hazards and attacks that threaten these installations. The SECUTRIZ tool presents an alternative assistance to the innovative design of industrial production systems. On the one hand, this tool allows the TRIZ method to be used, adopting these innovative solutions to propose solutions adapted to a design that takes industrial safety into account. On the other hand, it improves the proposed solutions while minimizing the operating time of the TRIZ contradiction matrix. A case study of a wind turbine is presented at the end of the article with a total of “N” parameters that will illustrate the value of the proposed model.

Keywords

Security and safety, Production Planning and Control, TRIZ, Control System Design.

Introduction

The life cycle of any product is considered from the very first phase of its creation. It is in this early stage that the product designer must think of every detail that will enable him to have a product that fulfills the tasks assigned to it in the best possible way, guaranteeing operational safety on the one hand, and a competitive price on the other. The most encountered design method in the literature is the TRIZ method alone, or combined with others methods. Nevertheless, it does not specifically address the aspect of industrial security in the first design phase.

This article’s objectives will be addressed in part through the search for an innovative design approach, specifically designed to optimize industrial security. The first part of this article presents a review of the literature on industrial security (IS) in system design.

The second part presents the generic process principle of the TRIZ method. The use of the matrix of technical contradictions proposed by Altshuller (Pavel & Vladimir, 2011) is discussed. In the third part, the SECUTRIZ matrix, including the parameters in pairs (parameters to be improved, deteriorating parameters), will be presented. The proposed solutions, which authors judge to be affecting the safety of industrial plants, are shown in matrix form. The final part will present a case study about a wind turbine, highlighting the usefulness of the tool implemented.

Definitions and literature review – Industrial Security

Definitions

The industrial security can be defined as the operational status of an industrial facility without exposing it or its environment (personnel, company turnover, environment, etc.) to hazards that could have devastating effects on the facility itself or its environment. This can be ensured by prevention, protection, or even repair measures. These human or material measures are the basis for the optimized design of the facility.

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Literature review

Tuptuk & Hailes (2018) focused on security in intelligent industrial systems, emphasizing the need to secure modern manufacturing environments. For Dogniaux (1978), two distinct methodologies (quantitative and qualitative approaches) were applied to a concrete case study. The quantitative approach demonstrated that an increase in production or productivity had a degrading effect on safety, while the qualitative analysis revealed that daily worker fatigue was more significant than the overall accident potential. Furthermore, according to Daniellou et al. (2010), industrial security and occupational safety are two highly complementary domains. As a result, both the prevention of industrial risks and the mitigation of occupational accidents must be addressed jointly. These authors presented an articulation of information, as shown in Figure 1, which illustrates the transmission channels between the reality on the ground and the adopted industrial safety policy.

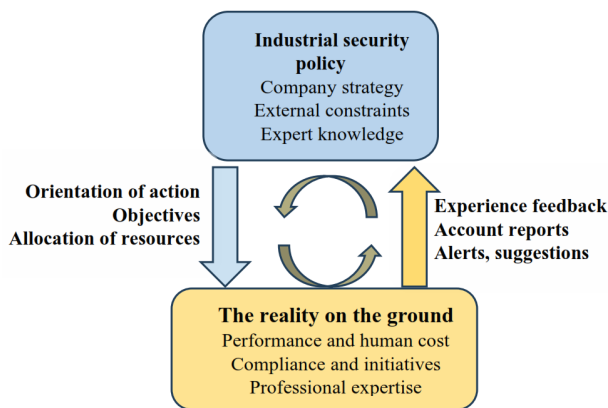


Fig. 1. Articulating top-down and bottom-up information (translated into English) (Daniellou et al., 2010)

Given the co-occupation of workplaces by humans and machines, systems known as Cyber-Physical Systems (CPS) have appeared in numerous publications (Rani et al., 2025; Li et al., 2023). Figure 2 shows the various components of a CPS.

Li et al. (2023) discuss the Cyber-Physical-Social enterprise framework, highlighting the importance of risk identification in this type of system, and proposing an analysis and design framework to address the security issue. Figure 3 shows the enterprise modeling framework, in which security is one of the pillars of the proposed model.

The flowchart (Figure 4) proposed by ISO 12100 (currently under revision) (Safety of Machinery, 2011) presents a risk reduction process using an iterative method: if the risk cannot be avoided, a change is made to the design in order to reduce it. If it does not work,

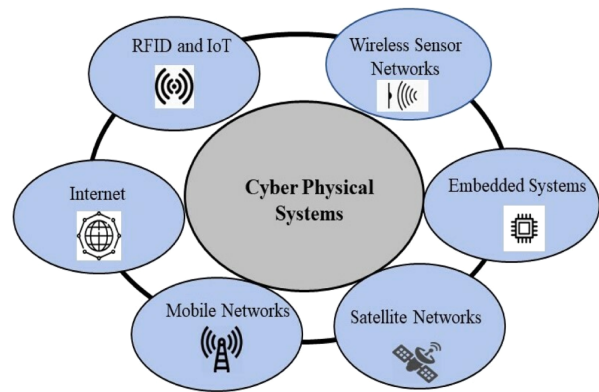


Fig. 2. CPS: A conflux of multiple technologies (Rani et al., 2025)

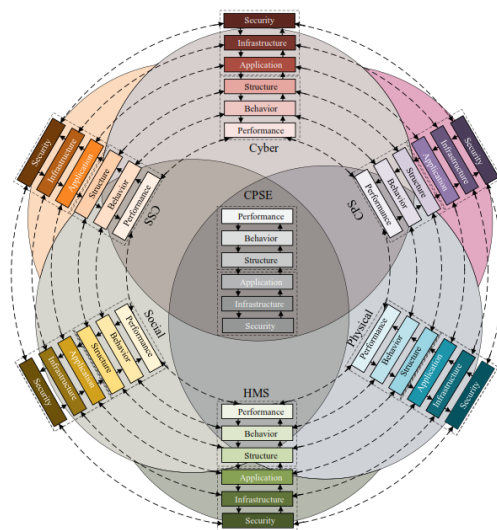


Fig. 3. Cyber-Physical-Social Enterprise Architecture Framework (Li et al., 2023)

protective devices are introduced. If this last proposal does not reduce the risk (according to the thresholds predefined by the designer), these thresholds are modified (Safety of Machinery, 2011). Figure 5 proposed by ISO 12100 (2010) presents the process of measures that can be implemented by the designer and the user. The effectiveness of these measures is clearly demonstrated if they are integrated into the design phase (Safety of Machinery, 2011). After the risk assessment, the protective measures are planned by the designer in three stages: first, the inherently safe design measures, then the protective devices and additional protective measures, and finally the information for the user. The designer is ultimately required to provide additional protective measures as part of a process that is not feasible within the scope of the intended use, and the residual risk is significantly reduced after the various protective measures have been implemented.

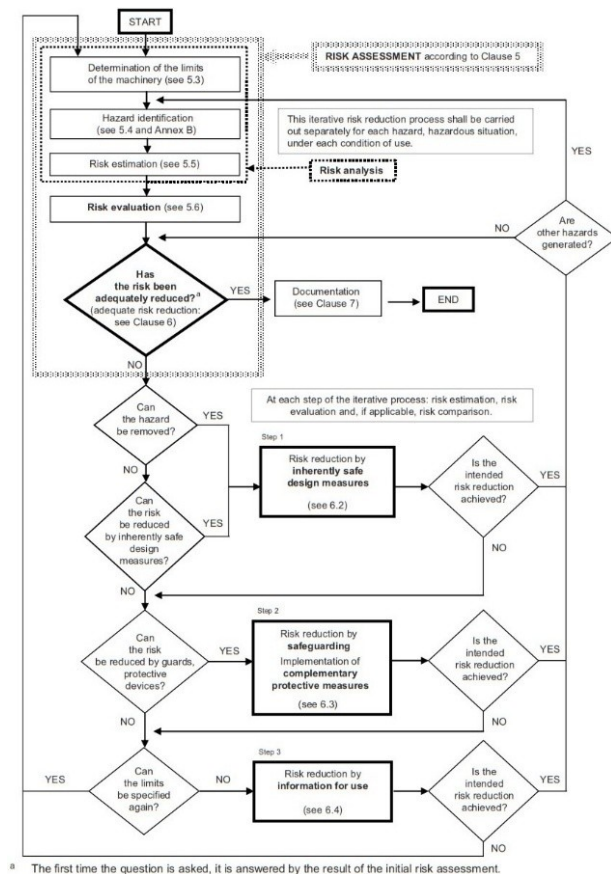


Fig. 4. Schematic representation of risk reduction process including iterative three-step method (*Safety of Machinery, 2011*)

Other authors have pointed out the importance of security in information processing in manufacturing plants, while Pal (2021) has highlighted the importance of the intelligent synergy of networked machines, in a hybrid structure (Internet of Things (IoT) and blockchain), to improve the performance of Modern Manufacturing Systems (MMS). The author stressed the need to further explore security issues, especially as MMS are characterized by their vulnerability stemming from the extensive exchange of data (information and knowledge) between partners (we can talk about machines), and all the risks that centralized control will bring to this type of system. Wang & Zhang (2023) address the issue of security in supply chain management, which is likely to be further developed thanks to the progress of Big Data technology, especially in the field of Artificial Intelligence (AI), and propose to combine a supply chain management model derived from the Internet of Things and cloud computing algorithms (Fig. 6).

The automation of decisions remains an objective sought by Machine Learning (ML). Bretones Cassoli et al. (2021) have evaluated computer security in a pre-

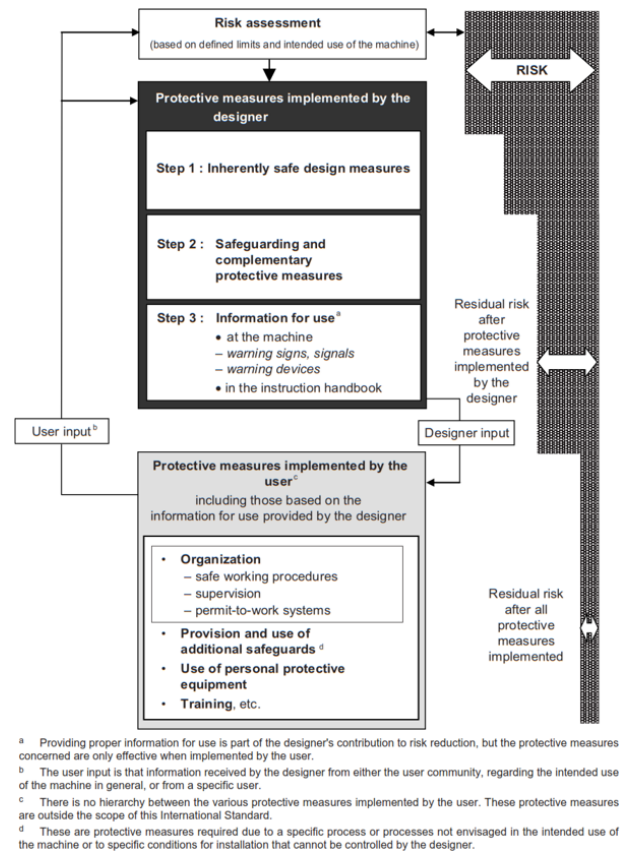


Fig. 5. Risk reduction process from point of view of designer (*Safety of Machinery, 2011*)

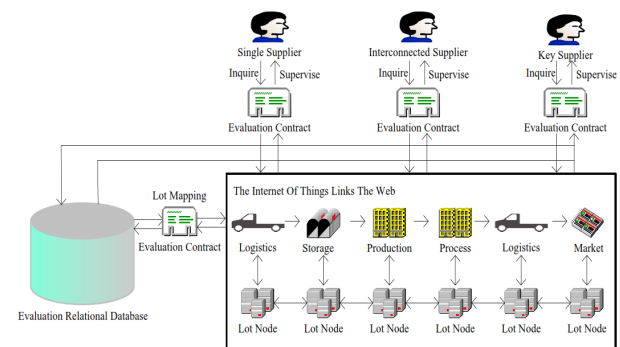


Fig. 6. Supply chain security management module and IoT information model (Wang & Zhang, 2023)

dictive maintenance solution and how this data can be affected. They concluded that the implementation of conventional computer security measures at infrastructure level can achieve an adequate level of security for applications based on Deep Learning (DL). Wells et al. (2014) have pointed out the need to educate the current and future manufacturing workforce about the drastic effects of cyber-attacks that can impact cyber-physical systems, especially as technology advances. In

this paper, the authors focus on innovation in industry, as this is an area to be conquered by manufacturers, given the rapid development of sought-after products that can change according to the wishes of an often unpredictable consumer. Innovative design therefore requires an approach that proposes solutions that meet the expectations of both the customer and the manufacturer. The TRIZ method will be the tool used in order to find solutions during the design phase.

In the cases discussed (risk-based design, CPS security frameworks, vulnerability of big data systems), security plays a crucial role during the design phase. In order to focus on security, authors will need a specific approach to this issue.

The TRIZ method

Altshuller, the creator of the TRIZ method (Fig. 7) (TRIZ stands for Teoriya Reshniya Izobretatelskikh Zadach in Russian. Theory of Inventive Problem Solving), had the idea of a method that could use common solving methods for all domains, which made this method, despite dating from 1946, one of the most widely found in the literature.

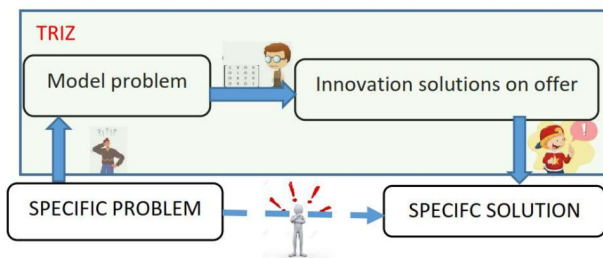


Fig. 7. Generic TRIZ process (Tahiri et al., 2023)

The concept of this method is summarized in Fig. 8. The resolution by the contradiction matrix allows to draw innovative proposals predefined by the creators of the matrix (Pavel & Vladimir, 2011), by combining the couple (improved technical characteristic, deteriorated technical characteristic). Tables 1 and 2 show, respectively, the 39 design criteria and the 40 innovation ideas proposed by Altshuller.

Hmina et al. (2020) used it in the early design phase, while Demirkesen & Zhang (2021) used the Lean concept and the innovative TRIZ method to prevent security problems in the construction industry, known as safety problem solving. In the article written by Ju (2004), improved product performance and reduced costs are also due to maintaining the weakest interactions between functional requirements. It can be said that the difficulty persists in finding design param-

eters that meet only specific functional requirements. Francia et al. (2018) used the TRIZ method combined with the QFD (Quality Function Deployment) method, exploiting PrinterCAD software, to come up with an innovative specific solution to a molding problem.

The distribution of TRIZ method usage (Fig. 8) indicates that the energy, electricity, and mechanical engineering sectors lead in terms of its use.

The analysis of contradictions is the most discussed according to Chechurin (2016), who attempted to conduct a bibliographic study of the method by analyzing approximately 1,200 indexed articles (SCOPUS) that demonstrated the unique and unbeatable capabilities of the method. The 100 most cited papers confirmed that this method is still used in product or process

Table 1
Altshuller 39 design criteria

No.	Parameter Name	No.	Parameter Name
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.	Accuracy of measurement
9.	Speed	29.	Manufacturing precision
10.	Force (Strength)	30.	Object-affected harmful factors
11.	Stress or pressure	31.	Object-generated harmful factors
12.	Shape	32.	Ease of manufacture
13.	Stability of the object	33.	Ease of operation
14.	Strength (Resistance)	34.	Ease of repair (Maintenance)
15.	Duration of action of moving object	35.	Adaptability or versatility
16.	Duration of action of stationary object	36.	Device complexity
17.	Temperature	37.	Difficulty of detecting and measuring
18.	Illumination (Light intensity)	38.	Extent of automation
19.	Use of energy by moving object	39.	Productivity
20.	Use of energy by stationary object		

Table 2
Altshuller 40 principles of TRIZ innovation

No.	Parameter Name	No.	Parameter Name
1.	The segmentation	2.	The extraction
3.	The local quality	4.	The asymmetry
5.	The combination	6.	The universality
7.	The pullout dolls	8.	The counterweight
9.	The contrary action prerequisite	10.	The anticipation
11.	The prevention	12.	The equipotential bonding
13.	The alternative	14.	The curvature
15.	The adaptability	16.	The action reduced or excessive
17.	The change of the dimension	18.	Mechanical vibration
19.	The periodic action	20.	The continuity of an action of usefulness
21.	The quick action for security	22.	The transformation of a detrimental effect in useful effect
23.	The enslavement	24.	The intermediary
25.	The self service	26.	The Copy
27.	The ephemeral cheap	28.	The evolution of the mechanical system
29.	The fluids	30.	The deformable
31.	The porous materials	32.	The color change
33.	The homogeneity	34.	The rejection and regeneration
35.	The change of ownership	36.	The phase transition
37.	The thermal expansion	38.	The oxidation
39.	The inert environment	40.	The composite materials

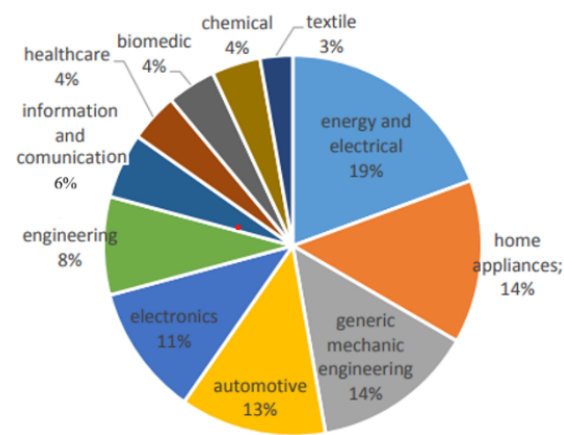


Fig. 9. Distribution of industrial sectors (Spreafico & Russo, 2016)

design (Chechurin, 2016). In the study conducted by Chechurin & Borgianni (2016), which also refers to the 100 most cited publications about TRIZ, the authors proposed an inventive product design. Despite the diversity of approaches to TRIZ, security seems to be essential throughout the life cycle of the product to be designed (Chechurin & Borgianni, 2016).

The improvement of this matrix has been the subject of study in several papers, including Mann & DeWulf (2003). They have the parameters of the original list of the matrix. Even if they have proposed new recommendations from the new inventions observed which were judged to be of good quality compared to the old patents which resulted in the old matrix, these authors have not judged whether the new matrix is better or not compared to the old one. Table 3 presents a comparison between the old and new parameters, where Mann & DeWulf (2003)

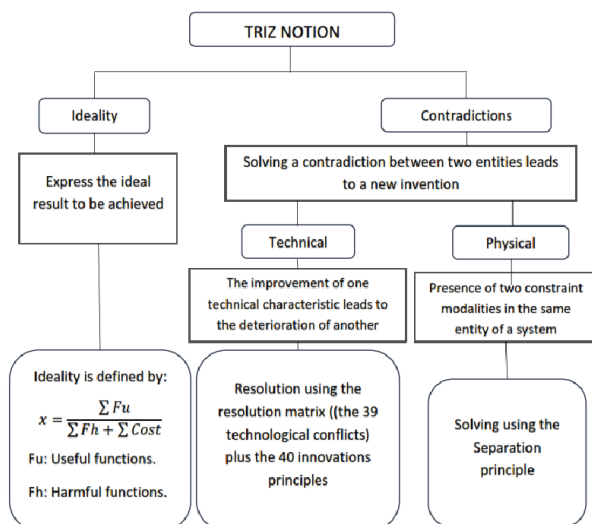


Fig. 8. TRIZ method concept (Omar et al., 2023)

Table 3
Parameters by category (Mann & DeWulf, 2003)

Categories	Parameters
<i>Physical parameters</i>	Amount of information
<i>Efficiency related parameters</i>	Function efficiency
	Noise
	Harmful emissions
<i>ility (reliability, durability,) related parameters</i>	Compatibility/ connectability
	Transportability
	Security
	Safety/vulnerability
	Aesthetics/appearance
<i>Manufacture/Cost Reduction Parameters</i>	Control complexity

have modified the names of some parameters and added others according to a new classification in the form of six categories of parameters (physical parameters, performance-related parameters, efficiency-related parameters, reliability/durability-related parameters, manufacturing/cost reduction-related parameters and “special category” measurement parameters), the second and last categories have not undergone any change, while the other four categories have been reinforced by other parameters. A summary of which is shown in Table 3 (Mann & DeWulf, 2003).

Livotov et al. (2019) proposed 160 innovations sub-principles, that can be consulted in their manuscript (Livotov et al., 2019).

Tahiri et al. (2023) mentioned the lack of avenues for finding innovative solutions within the current framework of technical contradictions, and encourage the scientific community to seek other ways to facilitate the transition between generic problems and generic solutions. The designers will next interpret in order to find specific solutions proposed to solve specific problems (Tahiri et al., 2023).

The flowchart in Figure 10 proposed by Huang et al. (2017) presents a process model for creative product design based on TRIZ and TOC (Theory Of Constraints). The model begins with an analysis of the evolution of the product’s technology, followed then by a second step to analyze the functional structure and

identify conflicts using CRT (Current Reality Tree) and CRD (Conflict Resolution Diagram). Conflict resolution is then proposed using the contradictory aspect (technical and physical contradictions) of the TRIZ tool. The final step consists of proposing alternative schematizations so that the designer can choose the optimal solution to meet the needs of the warpers, otherwise the product’s functional structure will have to be revised (Huang et al., 2017).

The first inventive models that triz focused on were mainly about mechanical aspects; consequently, most articles discuss TRIZ design method when applied to mechanical (Chechurin & Borgianni, 2016). Autors will attempt to propose a method based on this robust method (TRIZ) while focusing on the safety problem.

Proposed method-SECUTRIZ

Problematic

The main two fundamental pillars in industrial security are: first, technical devices responsible for detecting probable danger or attacks. Second, Human resources leading to structured organization and minimal risks. Figure 11 shows a layout of technical protection devices (TDi), and human resources to be provided against foreseeable attacks and hazards. For a more effective design, these can be modeled according to various scenarios.

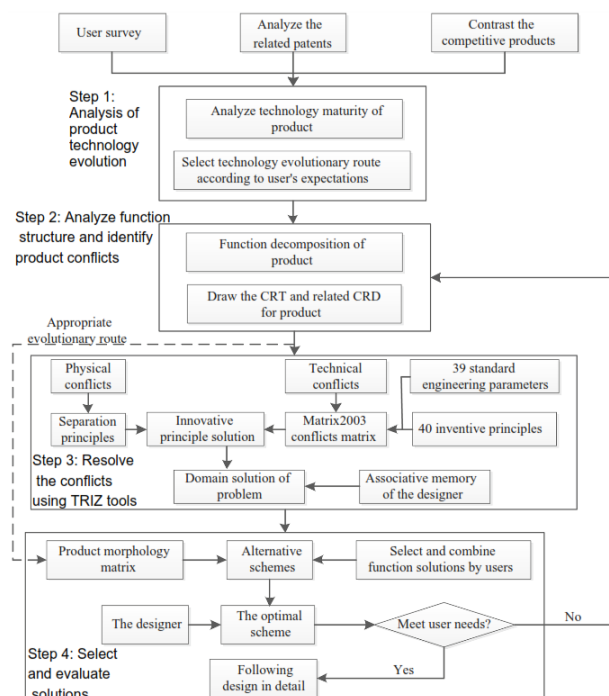


Fig. 10. Product innovation design model based on TRIZ and TOC (Huang et al., 2017)

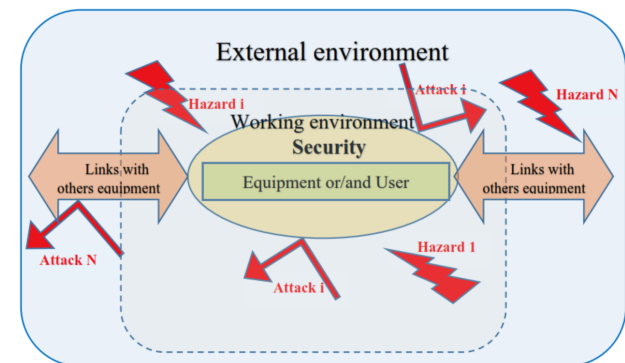


Fig. 11. Industrial Security as it has been defined

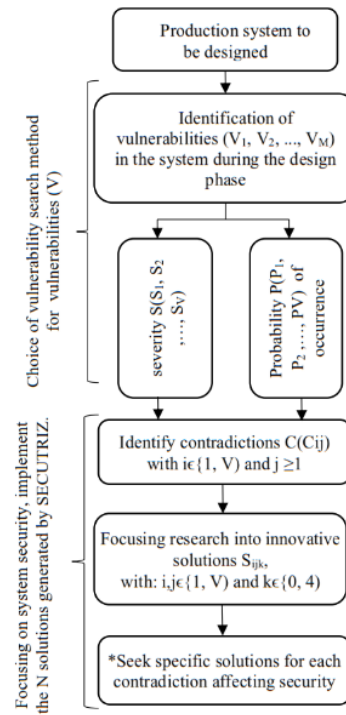
Exploiting TRIZ’s entire matrix of technical contradictions (39 properties) remains one of the possibilities for finding new, innovative design solutions. However, this search will require considerable design time. This work consists in adapting this matrix to potential risks in a production system, in order to ensure its safety and that of its environment, while exploiting the innovative solutions proposed by Altshuller.

SECUTRIZ approach

The method proposed by the authors consists of providing danger detection or attack mitigation devices, which will try to interpret or consider reactions with reference to the innovative solutions proposed by the TRIZ matrix approach to technical contradictions. These devices can be programmed (with the means offered by AI in future work). Authors have classified this protection according to two levels. Level 1 in which the protection consists of analyzing the system's weaknesses in order to propose remedial solutions, this level will not take into account the hazards that exist in the presence of a human (misuse or lack of organization). A second level of protection consists of taking the whole facility into consideration, and tries to prevent accidents and/or mitigate their consequences. The approach of this method is to list the vulnerabilities of the system in order to identify the technical contradictions associated with each vulnerability, and then to adopt the innovative solutions proposed by the SECUTRIZ matrix without having to scan all the proposals in the TRIZ parent matrix. The latter requires more analysis time, resulting in additional costs that increase design expenses and may lead to the same results. Finally, it is up to the designer to interpret the specific technological solutions associated with each contradiction (Fig. 12).

Risk elimination is practically not 100% guaranteed, since the hazard exists, so risk control in the design phase is the objective of this work. To this end, the authors will attempt to redefine a matrix they call SECUTRIZ, better adapted to the production system, and then use this tool to control risk in a wind turbine.

By analyzing the matrix of technical contradictions proposed by Altshuller, significant number of parameters will be assigned to the constituent blocks of a production system in a global view. Figure 13 shows these four blocks: first, a design block with the Shape parameter (P1); second, an environment block with the parameters (P3): Temperature, object affected harmful factors and object generated harmful factors. Third, a maneuver block classifying the parameters that can affect the functioning of an operator performing or supervising an action within a production system (loss of information, convenience of operation, currency complexity and Extent of automation). The last block is productivity, with the maximum number of parameters considered, including production time and parameters impacting the flows produced by the system (material or energy). Justifications are provided explaining the reasons for not taking some of the parameters in consideration (Table 4).



- i: vulnerability index, ranging from 1 to V;
- j: index of contradictions identified for each vulnerability, with a minimum of one contradiction per vulnerability;
- k: index of solutions proposed for each contradiction, which can have 5 values (according to the SECUTRIZ matrix table);
- *: Brainstorming or other methods may be used to find specific solutions.

Fig. 12. Algorithm SECUTRIZ

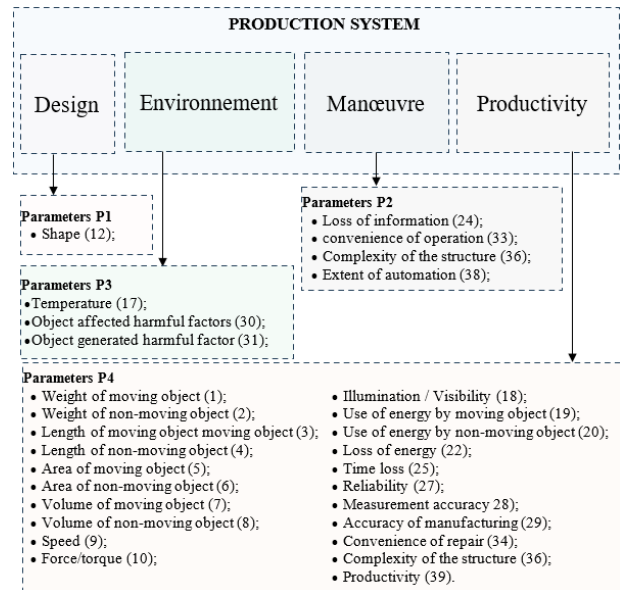


Fig. 13. Assigning TRIZ parameters to a production system

After reviewing the rows of the basic TRIZ matrix, which are derived from the 39 design criteria, authors will identify the couple (improved technical characteristic, deteriorated technical characteristic) that authors are convinced affect the safety of a production system. The following (Tab. 5) shows the parameters used to draw up the New Matrix. For each parameter, and indicate whether its increase or decrease could affect the security of the facility.

Table 4
Parameters not included in the new matrix

Parameters not retained	Marker in the TRIZ matrix	Pattern or parameter can be replaced by
<i>Tension-pressure</i>	11	Force/torque (10)
<i>Stability of object</i>	13	for (1) to (8)
<i>Strength of object</i>	14	force, torque (10)
<i>Durability of moving object</i>	15	Shape (21), Convenience of repair (34), reliability (27)
<i>Durability of immobile object</i>	16	
<i>Power</i>	21	Loss of energy (22)
<i>Waste of substance</i>	23	Productivity (39)
<i>Amount of substance</i>	26	
<i>Manufacturability</i>	32	
<i>Adaptability</i>	35	Shape (12) and complexity of the structure (36)
<i>Complexity of control</i>	37	Convenience of operation (33)

Table 5
Allocation of new parameters

Parameter to be improved (*)	(**)	Interpretation for an adaptation of parameters in deterioration/decrease or increase, affecting the safety of the production system (PS)
Weight of moving object (1)	1	Risk of Increasing/decreasing a moving mass
Weight of non-moving object (2)	2	Risk of increasing/decreasing static mass.
Length of moving object moving object (3)	3	Risk of long object movement (clutter, ...)
Length of non-moving object (4)	4	Risk to which a long object is exposed
Area of moving object (5)	5	Risk by minimizing the area occupied by a moving object

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Table continued from the previous column

Parameter to be improved (*)	(**)	Interpretation for an adaptation of parameters in deterioration/decrease or increase, affecting the safety of the production system (PS)
Area of non-moving object (6)	6	Risk of reduction in area occupied by a static object
Volume of moving object (7)	7	Risk of decrease/increase in volume of a moving object
Volume of non-moving object (8)	8	Risk of decreasing/increasing the volume of a static object
Speed (9)	9	Risk of Decreased/Increased Speed
Force/torque (10);	10	Risk of Increased/decreased force/torque
Shape (12);	11	Design modification risk
Temperature (17)	12	Risk of temperature change
Illumination / Visibility (18)	13	Risk of change in visibility level
Use of energy by moving object (19)	14	Risk of energy being used by a moving object
Use of energy by non-moving object (20)	15	Risk of energy being used by a static object
Loss of energy (22)	16	Risk of energy loss
Loss of information (24)	17	Risk of information loss
Time loss (25)	18	Risk of lost production time
Reliability (27)	19	Risk of loss of reliability
Measurement accuracy (28)	20	Risk of loss of measurement accuracy
Accuracy of manufacturing (29)	21	Risk of loss of manufacturing precision
Object affected harmful factors (30)	22	Risk of being affected by harmful factors
Object generated harmful factor (31)	23	Risk of object presenting harmful factors
Convenience of operation (33)	24	Risk of deterioration in operating comodities
Convenience of repair (34)	25	Risk of deterioration in repair comodities
Complexity of the structure (36)	26	The risk of a complex structure
Extent of automation (38)	27	Risk posed by excessive automation
Productivity (39)	28	Risk of increasing production

*Parameter ranking in Altshuller's original matrix, based on the publication of (Pavel & Vladimir, 2011).

** Parameter ranking in the SECUTRIZ matrix.

The proposed SECUTRIZ matrix is shown in Figure 14 with the 28 selected parameters (following analysis and evaluation of the parameter encapsulation (Table 5)), and the same solutions proposed by Alt-

		Which properties of the systems change for the worse																											
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Fig. 14. The SECUTRIZ matrix for taking security into account in a power generation facility

shuller's original matrix are retained. Figure 15 shows the integration of the matrix into a production system design process, with the aim of finding innovative solutions that take risk situations into account as a priority in the search for optimal solutions.

The strength of the SECUTRIZ matrix lies in risk management. According to standard ISO 31000, enables the creation and protection of value, improving performance, encouraging innovation, and supporting the achievement of objectives (ISO 31000, 2018).

Comparability of SECUTRIZ with other methods

The authors performed a comprehensive comparative evaluation of the SECUTRIZ method in relation to Altshuller's baseline approach, as well as to its hybridization with the TOC method and with the QFD method. Table 6 details the underlying principles of each approach, whereas Table 7 provides a systematic comparison of their respective strengths and limitations.

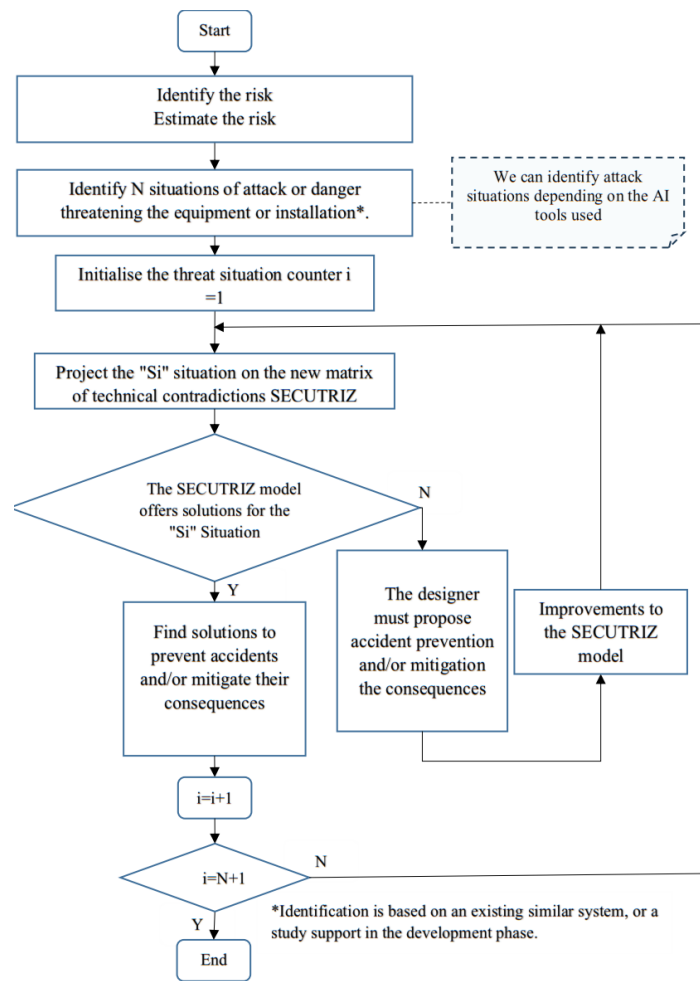


Fig. 15. Flow chart for integrating industrial safety into the proposed SECUTRIZ method

Table 6
Comparison of methods

Methods	Principles
TRIZ (Chechurin & Borgianni, 2016) (<i>Matrix of contradictions</i>)	resolution by means of the Matrix of contradictions produces innovative proposals predefined by the matrix's creators;
TRIZ et TOC (Huang et al., 2017)	TOC identifies conflicts using tools such as the Current Reality Tree (CRT) and the Conflict Resolution Diagram (CRD), then searches for innovative solutions using TRIZ.
TRIZ et QFD (Francia et al., 2018)	QFD translates customer needs into design parameters, while TRIZ looks for innovative solutions.
SECUTRIZ	focus the list of parameters proposed by the SECUTRIZ matrix on system security.

Case study / Contribution of the method: wind turbine

System overview

In a wind turbine, with its components shown in Figure 16 and its flowchart shown in Figure 17 explaining the chronological order of the energy conversion process. A system analysis makes it possible to identify the parameters that must be taken into account in order to identify risk situations – which should be avoided in the future – or to strengthen the system's resilience through appropriate design.

The study by Zhuang & Yuan (2024) focused on the structural parameters of the blades (wave frequency, torsion, bending stiffness, and center of gravity), which have a major impact on the frequency and speed of flutter; hence, the need for a design that takes into account wave frequency and torsion, as well as torsional stiffness (Zhuang & Yuan, 2024).

Table 7
Comparison of methods

Methods	Highlights	Weaknesses	Observation
TRIZ (Chechurin & Borgianni, 2016) (<i>Matrix of contradictions</i>)	A wide range of innovative solutions.	The relevance of transitions from predefined solution paths and specific solutions adopted.	It's been around for 80 years, and it's still usable.
TRIZ et TOC (Huang et al., 2017)	Quickly locate and understand conflicts in the system to be analyzed	Need for other tools to carry out the task of identifying and locating conflicts. Wide spectrum of solutions; Complexity	Many researchers believe that the combination of OCD and TRIZ is useful for analyzing, identifying and resolving conflicts.
TRIZ et QFD (Francia et al., 2018)	Detailed translation of customer requirements into design specifications	Complexity; Time cost;	Targeting innovative solutions
SECUTRIZ	Reduced time to find solutions by focusing the search for innovative solutions on the security aspects of the system to be designed	Eliminated research avenues can lead to relevant solutions;	Focus on security and innovation.

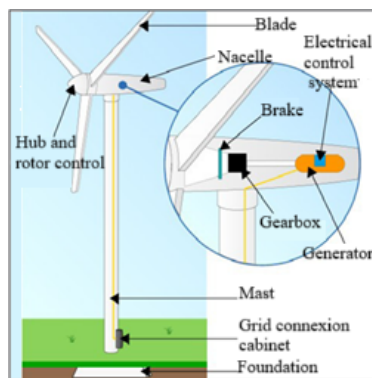


Fig. 16. Main components of a wind turbine (translated into English) (The Wind Turbine Guide, 2025)

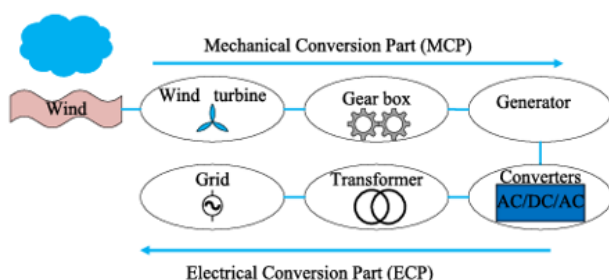


Fig. 17. Wind turbine system (Tehrani et al., 2024)

In the manuscript by Ziyang Chen et al. [Chen et al. \(2023\)](#), the authors attempted to improve the stability of power generation by considering the four families of disturbances: non-modifiable environmental

disturbances, unmodeled systemic disturbances, disturbances due to wind variability and dynamic loads, and disturbances due to external and random factors. A representation in the form of a SysML diagram (Block Definition Diagram (BDD)) is shown in Fig. 18, which identifies the three blocks of the overall system: the transformer block, the converter block and the system support block.

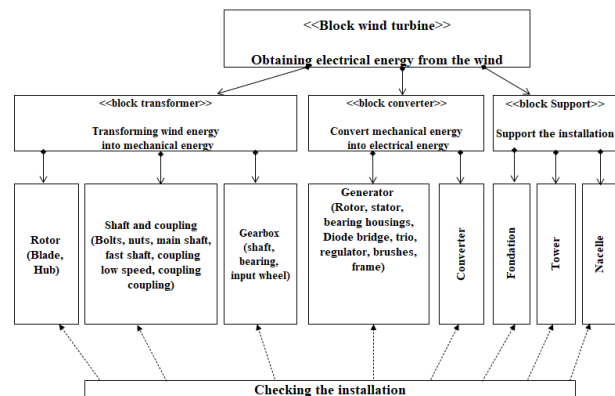


Fig. 18. SysML diagram – “BDD” block definition diagram for a wind power plant

The main objective of a wind turbine is to increase productivity (28–39), by increasing production speed (9–9), system reliability (19–27), measurement accuracy (20–28), accuracy of manufacturing (21–29), convenience of operation (24–33), convenience of repair (25–34). Progress in one or more of these parame-

ters will result in losses in other parameters. Table 8 presents a non-exhaustive list of the various contradictions observed in this facility.

The technical devices required to improve security in a production facility (in the case of electrical energy production) can be designed on the basis of the risk parameters that were identified. In this case study, the authors focused on one risk parameter in each technological solution represented in the BDD diagram in Figure 18. The 8 parameters ($N = 8$) they classified as generating harmful factors are shown in Table 8. Based on each attack situation, then proposed innovative solutions:

Increase productivity (28)

→ Object generating harmful factors (23).

A first level of protection ensures safe operation thanks to innovative system designs featuring technical devices that increase operational safety. The use of appropriate algorithms in order to predict hazards of either human origin (misuse, etc.) or natural origin (hot environment, strong wind, etc.) will make it possible to prevent and/or mitigate the consequences of these hazards.

First, the choice of a method based on TRIZ is justified by the multitude of solution models that it offers, giving it an advantage over other methods. Second, a simple comparison of solution search times, on the one hand, using a broader base of proposed solution models presented by the TRIZ method alone or combined with other methods (including solutions that are not the subject of this research, which does not focus on system security), and on the other hand, by adopting the search models of the SECUTRIZ method (which focuses on the security aspect and can propose other innovative solution models), shows that the time allocated to searching for a model using the latter is less than that allocated to searching using other models or methods.

The solutions proposed by the authors adopting the SECUTRIZ scenario are shown in (Tab. 9). The limitation of the solution search paths imposed by this scenario (focusing only on problems directly related to the improvement of the security in the facility) has significantly reduced the amount of work required.

Table 8
Contradiction in the wind turbine system

Parameter to be progressed (SECUTRIZ–TRIZ)	Parameter will change for the worse affecting system security)	Innovative solutions proposed by the TRIZ contradiction matrix
(28–39)	(23–31)	35 Change of ownership 22 Transforming a harmful effect into a useful one 18 Mechanical vibration 39 Inert environment
(9–9)	(22–30) (23–31)	1 Segmentation 28 Evolution of the mechanical system 35 Change of ownership 23 Servo control 2 Extraction 24 Intermediary 21 Fast action for safety
(19–27)	(18–25)	10 Anticipation 30 Fluids 4 Asymmetry
(20–28)	(18–25)	24 The intermediary 34 Rejection and regeneration 28 Evolution of the mechanical system 32 Color change
(21–29)	18–25	32 Color change 26 Copying 28 Evolution of the mechanical system 18 Mechanical vibration
(24–33)	(27–38)	1 Segmentation 34 Rejection and regeneration 12 Equipotential bonding 3 Local quality
(25–34)	(27–38)	34 Rejection and regeneration 35 Change of ownership 7 Pulling dolls 13 The alternative

Table 9
Examples of parameters that change for the worse after seeking to increase plant productivity

$N =$	Technological solutions	Parameters that change for the worse as productivity increases (28)	Presentation of attack situations	Innovation solution
1	Rotor	Speed (9)	Deterioration (strong wind)	Gearbox; Choice of blade material; Variable blade stiffness; Braking system with energy recovery; Vertical wind turbine;
2	Shaft and coupling	Force/ torque (10)	Damage to the shaft (torsion, etc.)	Torque damper (resort);
3	Gearbox	Speed (9)	Shaft jamming (guide element fatigue, etc.)	Choice of materials
4	Generator	Temperature (17)	Overloading (bending, fatigue, etc.)	cooling system (shape and fluid circulation)
5	Converter	Temperature (17)	Component losses (heating)	Cooling system
6	Foundation	Volume of non-moving object (8)	Land erosion (wind, natural disaster)	Monitoring sensor; Foundation structure;
7	Tower	Weight of non-moving object (2)	Weakening of the structure (material fatigue)	Monitoring sensor; Structure hydrodynamique;
8	Nacelle	Weight of non-moving object (2)	Dismantling (vibration effect)	Monitoring sensor; Assemblage permanents /démon Tab. avec éléments de freinage;

Conclusions & Outlook

The matrix of technical contradictions proposed by its inventor, Altshuller, remains a powerful and innovative tool specialised in searching for innovative solutions in all fields, particularly mechanical engineering. However, the overall use of this matrix can be very time-consuming for less complex situations.

The proposal of the SECUTRIZ matrix, which deals with the industrial security aspect in the design phase, can considerably reduce the time needed to find innovative solutions proposed by the TRIZ parent matrix. The new proposed solutions can be modified, replaced or even reinforced by other solutions, all this while abiding by the security integration flowchart in the design phase.

In the futur, a hybrid method that can bring together several approaches is conceivable, in order to optimise the search/proposal time for a safer, more innovative solutions, and can take advantage of what prediction algorithms in the AI field have to offer.

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