Technology Choices for Production of Low Cost and Sustainable Electricity: The Case of a Malagasy State Owned Company with TRIZ Method

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Abstract— **This article aims to identify the potential pragmatic and realistic technological choices based on the Malagasy state company's systems performance taking into account its technical, geographical and environmental adaptability for the production of electricity. This study employed the TRIZ method, an innovative design method, to generate new concepts systematically. Contradiction Matrix, 11 separation principles and 76 Standard Solutions were used for the survey. The assumption from TRIZ engineering methodology, innovative solutions are conceivable in the principle of ideality. As a result, TRIZ is moving towards a technological choice based on an energy mix using local and renewable energy sources implanted in political, commercial and tax environment favorable to an investment, and easy to integrate into an interconnected network. It is a contribution to the resolution of power outages in Madagascar and can serve as a basis for strategic decisions regarding the supply of electricity in the long term.**

Keywords— ***Adaptability, Electricity Cost, Sustainable electricity, Technological choices, TRIZ.***

I. INTRODUCTION

According to the World Bank study results for the preparation of the 2015 Doing Business Report; Madagascar is classified as the 189th country in term of electricity access rate. In fact, with a national electricity access rate of 15% in 2014, the country faces major difficulties in electrification, both in urban and rural areas. Therefore, the Big Island does not escape the problem of most African countries. Indeed, C. Heraeux confirmed that Africa is the continent of paradoxes: it is at the same time an energetic giant by the resources which are at her disposal. Also, has she an electric dwarf by the real powers over her in which it can be based today. [1]. This statement is confirmed for the case of Madagascar. More specifically, at the beginning of the 2000s, the growth rate of the sector remains very low [8]. Historically, in the case of Madagascar, the production and supply of electricity are generally provided by the JIRAMA State Company's network which brings electricity to the urban areas. And that are provided also by the Rural electrification Agency (ADER) network, which is a structure linked to the Ministry in charge of Energy to promote and develop electrification in rural areas. But according to the power installed on all the territory of Madagascar, the production of Electric Energy is mainly ensured by the State Company JIRAMA. In fact, JIRAMA is a Madagascar national company which provides water and electricity. JIRAMA produces and ensures the electricity widespread in Madagascar, as well as it supplies drinking water and industrial water throughout the country. The installed capacity of this Company is estimated at 484MW in 2015 according to two means of production including 161 MW of hydroelectric source and 323MW of diesel thermal. But in 1999, the electricity sector underwent a reform on the governance and management of the national electricity system. This reform of the electricity sector can be summed up, firstly by the liberalization of all activities in the sector's value chain. Secondly, through the creation of bodies directly attached to the Ministry of Energy, including the Electricity Regulatory Office (ERO) and the ADER. This liberalization thus means the end of the monopoly of the State and JIRAMA in the exploitation of the facilities of production, transmission and distribution of Electricity in Madagascar. However, this liberalization of the sector does not mean deregulation, as the sector is still regulated. The Ministry of Energy, the ORE and the ADER constitute the State structures that work for the development of the electricity sector in Madagascar [7].

But F. Bertholet, World Bank expert says that the image of the evolution and performance of the Malagasy electricity sector over the last decade appears mostly negative. The clients of the public company JIRAMA had to complain about repeated episodes of load shedding. The tariff's increase in the result of the rise in prices of fuel does not improve the service quality nor the access rate. In fact, the JIRAMA Company is currently in a period where all the performance indicators are turning red, weakening its capacity for self-financing and slowing down the necessary maintenance of production facilities. New connections have been rationed since 2004, hampering the development of new economic activities. In short, the Malagasy electricity sector is perceived as in a state of crisis and as constituting a bottleneck for the economic and social development of the country [4]. Theoretically the field of energy, and more particularly electricity, combines economic, political, social, technical, environmental and climatic issues [1]. In other words, this domain is comparable to a complex system of which several inseparable factors dictate its performance. According to Eberard, in sub-Saharan Africa, including Madagascar, a number of "paradoxes" characterize the production of electricity, such as lack of production

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capacity, irregular supply, very high prices and access to the electricity grid very limited [2].

Madagascar is not immune to these paradoxes. In fact, especially in the case of JIRAMA, the poor performance of the company is reflected in the following factors:

- A high production cost;
- Poor quality service and reliability of the system;
- Inaccessible Electrical energy to all;
- Uninsured durability.

From the analysis, the high production cost was chosen as a research problem. His choice was determined by his effect on the performance of JIRAMA. Indeed, the high cost of production is a recurring problem with the company JIRAMA.

Due to the technological choice based on the thermal, the use of fuels has a negative impact on its cash flow, which weakens the financial system of the company. Hence the position of our research question: "What pragmatic and realistic technological choices rely on the JIRAMA's systems performance taking into account its technical, geographical and environmental adaptability would make it possible to reduce the production cost of Society? " According to our research question, and regarding to the innovation our research hypothesis is formulated as follows,: "An innovative and sustainable technological choice with a lower production cost can be conceivable with the TRIZ approach".

The objectives of this paper are:

- To determinate the sustainable and low-cost technological choice for JIRAMA with the TRIZ method;

- To determine the best options for the implementation of the technology;

II. MATERIALS AND METHODS

A. *Overview*

Designed in 1946 by the Russian engineer Genrich Altshuller, the TRIZ or the theory of inventive problem solving, is a method of systematically exploring areas of solutions to generate new concepts. This method makes it possible to approach inventive problems, that is to say problems presenting at least one contradiction (the improvement of one characteristic result in the deterioration of another characteristic) and not including any known solution, and to take advantage of similar solutions applied in other areas to find a solution. The aim is to put our capitalized industrial knowledge to good use, broaden the spectrum of investigation in the creativity phases, in order to eliminate a contradiction and find a solution to an inventive problem, rather than finding a compromise. In TRIZ, the process of solving a problem consists in transforming the specific initial problem into a standard problem model. Then thanks to the TRIZ tools, standard solutions are suggested; and finally the implementation phase of this solution to the specific problem. This process is shown schematically in the following figure [3],[10].

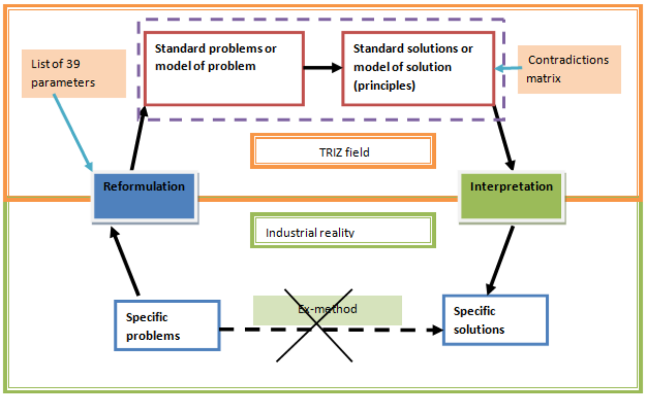

Fig. 1. Research process through the TRIZ based problem resolution principle

B. *The basic principles of TRIZ*

TRIZ is based on certain principles that emerged from research carried out by G. Altshuller on solving problems [5]:

- Existence of systems evolution logical trends

There are "laws" of systems evolution. These laws can be discovered, studied and formalized to be applied to problem solving.

- A contradiction as a cause of any problem:

During their evolution, the systems overcome contradictions arising from the opposition of the laws of nature to these evolutions.

- The specific conditions of the problematic situation:

Any problem can only be solved by analyzing the specific conditions of the problematic situation. The objective of TRIZ is therefore to provide, with tools and methods, a direction in the right one as shown in the following diagram:

- The need for an abstraction of knowledge:

TRIZ is a means of access to an abstraction of knowledge, the latter being necessary to overcome any contradiction and solve it by appealing to a wide knowledge.

C. *The concepts generation tools in TRIZ:*

The following table summarizes the tools used to solve problems according to the contradiction determined.

TABLE I. PROBLEM SOLVING TOOLS WITH TRIZ

Problems Model	Associated Resolution tools
Technical Contradiction	Matrix of Contradiction
Physical Contradiction	Eleven Separation Principles
Material - Field	Seventy Six Standards

D. *Resolution of Technical Contradictions: Matrix of contradiction*

This tool helps the designer to find the most likely innovation principles to solve our problem, and lead to an innovative solution and not a compromise. This matrix is the result of studies aimed at highlighting patterns of typical problems and expressing them in the form of conflicts between design parameters. There are 39 main types of parameters in conflict during a search for contradiction [6]. The resolution matrix of the technical contradictions presents these 39 parameters on its two axes as the following extract shows:

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TABLE II. MATRIX OF CONTRADICTION

Characteristic to be improved \ Characteristic that is getting Worse		1 Mass of mobile object	2 Mass of immobile object	3 Length of mobile object	4 Length of immobile object	5 Length of immobile object	… …
1	Mass of mobile object		-	15,8 29,3 4	-	29,1 7 38,3 4	…
2	Mass of immobile object	-		-	10,1 29,3 5	-	…
3	Length of mobile object	8,15	-		-	15,1 7 4	…
4	Length of immobile object		40,2 9	-		-	…
5	Surface of mobile object	2,17	-	14,1 5 18,4	-		…
…	…	…	…	…	…	…	…

It suffices to select the characteristic to be improved on the vertical axis, and the one that is getting worse as a result of the improvement on the horizontal axis (we try to have the parameters that come closest to those present in the technical contradiction). The intersections of the selected parameters contain the references of the recommended innovation principles.

E. Resolution of physical contradictions: 11 separation principles

On the basis of his patent analysis, Altshuller formalized eleven principles to resolve a physical contradiction. These are used to separate opposite properties in space, time, and between the system and its components. These methods are a set of generic rules or eleven principles of resolution to separate the contradictory properties of a physical contradiction, without compromising [9][11].

TABLE III. THE ELEVEN (11) SEPARATION PRINCIPLES

Division of contradictory properties	
1	In space
2	In time
Systems transition (1)	
3	Assembly of homogeneous or heterogeneous systems into a super system
4	Transition from a system to an antisystem
5	The system with its parts have property C
Systems transition (2)	
6	Switching to a system operating at the micro level
Phase transition	
7	Replacing the phase state of a part of the system
8	'Dualistic' phase state of a part of the system (depending on working conditions)
9	Use of the phenomena accompanying the phase transition R
10	Replacing a one-phase substance with a two-phase substance:
Physico-chemical transition	
11	Appearance / disappearance of the substance following decomposition / combination

F. Development of concepts based on Su-Field analysis using the 76 standards

The Standards are a system of rules used with Su-Field Model of Conflict to develop concepts from the highlighted Technical and Physical Contradictions and using available resources as well as physical effects. The 76 Standards are grouped into five broad categories [9],[10]:

- Su-Field Construction and Destruction: 13 Standards

- Su-Field Development: 23 Standards

- Transition to super-system or micro-level: 6 Standards

- Measurement and detection: 17 Standards

- Implementation of Standards: 17 Standards

In practice:

- A Standard is a recommendation to transform the system to eliminate the problem. It represents a solution used frequently for a specific type of problem.

- Standards are grouped by constraint, allowing the user to quickly find appropriate solution concepts.

- To use this tool, it is first necessary to identify the class of the problem (according to the model resulting from the Su-Field Analysis), then to choose a group of Standards for this type of problem.

- The Standards are not linked to any particular technical area and can be used to transfer powerful solutions from one domain to another.

III. RESULTS

A. The system specifications that we want to design or improve:

In order to meet our objective, there are some essential specifications for the technology to be identified. This list is not exhaustive but will allow us to orient our fields of research.

TABLE IV. PARAMETERS FOR THE TECHNOLOGY TO IDENTIFY

N°	Parameters	Subparameters
01	The energy source	-Technological level - Availability of raw materials
02	The supplied power	-
03	The output	-
04	The lifetime	-
05	The cost of production	-investment cost - Exploitation cost
06	Pollution / Contribution to climate change	--CO_2 emissions --Radioactive waste -
07	The flexibility of use	

- The energy source can be translated as the process of transforming primary energy into electricity. It breaks down into two parameters, including the technological level and the availability of raw materials.

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- The power supply defines the demand to be satisfied. Indeed, the choice of a technology depends on the level of power to be supplied.
- The output is a key parameter for evaluating the effectiveness of a technical system. Theoretically, this parameter represents the ratio between the electrical energy produced and the primary energy used during the transformation.
- The lifetime of the power station, this means the equipments and installations used for the process commissioning.
- The cost of production is the key parameter of our system. This cost includes investment and operating costs.
- Pollution / Contribution to climate change is indissociable from our system given the goal of having sustainable technology. It can be translated as the level of greenhouse gas ($CO2$) emissions or radioactive waste.
- Flexibility of use represents the level of adaptability of the system or technology according to geographical, environmental and commercial conditions (demand, current and future market structure, etc.).

B. General solution concept:

According to the restrictions of the specific situation obtained previously, we can thus already define a general concept of solution. Several parameters have been defined. Our concept of solution could be formulated as follows: "Levels of technology parameters: energy source, power output, efficiency, lifetime, pollution and flexibility of use must have values (specific characteristics) in order to meet a cost of electricity production that tends to zero". We should note that at this level, it is still difficult to identify the relationships that may exist between these different parameters, which will be the subject to be analyzed later (parts definition of the elements in conflict and identification of the contradiction at the origin of the conflict).

C. Identification of contradictions and Su-Field Model

1) Physical contradictions:

Physical Contradiction 1 (PC1):

"The energy source of the technology must be available in Madagascar to reduce the cost of operation, but must not be available in Madagascar to reduce the risk of environmental destruction".

Physical Contradiction 2 (PC2):

"The energy source of the technology must be renewable to reduce the cost of operation, but must not be renewable to reduce the investment cost".

2) Technical contradictions:

Technical Contradiction 1 (TC1):

"If the efficiency of the technology is great, the investment cost increases".

Technical Contradiction 2 (TC2):

"If the pollution of the technology is low, the investment cost is high".

Technical Contradiction 3 (TC3):

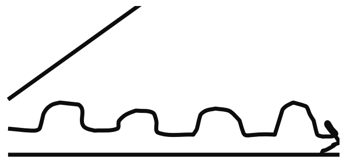
" If the life of the technology is long, the investment cost increases".

3) <u>Su-Field Model N ° 01:</u>

Substance S2: Operating Cost and Environment
Tool S1: Raw materials
Field C: Source of energy

Model construction:

Model N ° 01



System evaluation:

⇨ Model N ° 01: Complete model of the Su-Field but harmful link

D. Resolutions and generation of concepts:

1) Physical Contradiction 1 (PC1):

Analysis and choice of the principle:

According to the statement of the contradiction, the objective is to reduce the cost of exploitation as well as the risk of destruction of the environment. Indeed, having this ideal result requires both a source of energy that should be both available and unavailable in Madagascar. This conditionality is considered to be an agreement of incompatible actions. It is therefore possible to apply separation in space (principle 1) and separation in time (principle 2) principles. These principles mean that at a certain moment and in a certain place, the object here "the energy source" has the property A "available" and another, the property Not-A "not available".

Specific solutions (SS) to propose:

- **SS1:** Energy mix through the development of hybrid systems with minimum land use and $CO2$ emissions. This solution stems from the first principle which is separation in space. The objective is to reduce the operating cost while limiting the risks to the environment. Indeed, as it has already been developed in the Restrictions section of the specific situation /determination of the contribution made by adjacent systems. Madagascar has a significant resource in renewable energy and has a significant potential in coal. This is an important solution to reduce the operating costs of the power station. The problem lies in the exploitation of these resources on the territory. It is therefore essential to reduce this land occupation. One can opt for a minimum of central while ensuring interconnection of the different areas to be electrified.
- **SS2:** Exploitation of marine energy sources or offshore system:

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This option can be considered as a separation in space. Indeed, the installations do not require occupancy that can create major risks in the territory. However, risk analysis on the marine environment should be conducted. And in this case, interconnections are essential.

2) Physical Contradiction 2 (PC2):

Analysis and choice of the principle:

The physical contradiction is focused on the ownership of the energy source. Depending on the objectives, it should be both "renewable" and "non-renewable". This assertion seems impossible. On the other hand, the energy source conditions the technology to be applied. Since technology is a technical system, it is therefore possible to apply principle 3 or system transition. This principle is formulated as follows: "we can increase the efficiency of a system (at any stage of its evolution) by the systemic transition, in particular, by uniting the system with another system (or systems) in bi- or poly - system more complex »

Specific solutions to propose:

Here, the problem can be formulated as follows: how to reduce the investment cost of renewable energies? The ideality is therefore a technology using renewable energies with a minimal investment cost. Starting from this principle 3 or transition of the system, the closest solution is to have a hybrid technology by combining renewable and fossil sources. It is a poly-system that is already used by JIRAMA if one refers to its different technologies of electricity production (super interconnected network system: hydraulic and thermal). But we can push this principle on the activities of the power station itself. In fact, if we consider a hybrid technology in activities, that is to say, capable of producing both electricity and performing other value-adding functions, this principle will reduce the costs of investment while reducing the payback period of invested capital. On the other hand, the energy efficiency of the facilities is also a solution. Practically one can propose the following technological choices:

- **SS3**: Hybrid system of energy sources and activities
- **SS4**:Energy efficiency of facilities

3) Technical Contradiction 1 (TC1):

Identifications of the TRIZ modeling parameters:

Electricity is energy produced by the movement of electrons. It comes from a power station with a technology. It is transportable via networks from a power station through transmission and distribution lines. It is therefore comparable to a mobile object. On the other hand, from the point of view of TRIZ, the power station (technology) is assimilated as being an immobile object. As a result, the output of a generating station which is by definition the ratio of the energy produced to the incoming (used) energy is comparable to the productivity (39), the reliability (27) and the speed (9).

On the other hand, the investment cost being considered as the expenses necessary for the implementation of a plant. It can therefore be assimilated as the energy expended by the immobile object (20) and the weight or mass of the immobile object (2).

TABLE V. PARAMETERS FOR TECHNICAL CONTRADICTION 1 (TC1)

Characteristic to be improved	productivity (39), reliability (27), speed (9)
Characteristic that is getting worse	energy expended by the immobile object (20), mass of the immobile object (22)

Application of contradiction matrix:

The use of the resolution matrix of the technical contradictions gives the results figured in the following table:

TABLE VI. EXTRACT FROM THE TRIZ MATRIX FOR TC1

Characteristic that is getting worse / Characteristic to be improved		Mass of immobile object	energy expended by immobile object
		2	20
09	speed		
27	reliability	3, 10, 8, 28	36,23
39	productivity	28, 27, 15, 3	1

The matrix gives 9 principles with 40 possible.

TABLE VII. SOLUTIONS FOR TC1

Principles of solutions (generic solutions)	⇒ Redesign or mechanics substitution (28): two (02) times ⇒ Local quality or internal remodeling (03): two (02) times ⇒ The anti-weight (8): one (01) time ⇒ Segmentation (1): one (01) time ⇒ The enslavement (23): one (01) time ⇒ Phase transition (36): one (01) time ⇒ The preliminary action (10): one (01) time ⇒ Dynamics, optimization (15): one (01) time ⇒ Affordable accessory, ephemeral (27): one (01) time
Specific solutions to propose:	➢ SS5: Opt for technologies whose fields of interaction between elements are mainly electric, magnetic or electromagnetic (electronic) fields; ➢ SS6: Ensure that each part of the plant / technical system (technology) operates in the most suitable conditions for its operation: the feasibility studies should be pushed and should incorporate an optimization; ➢ SS7: Establish an enabling environment for investment: favorable trade laws, minimum taxes, zero corruption, etc. ➢ SS8: Properly choose the location of the power plant and distribution areas in an area with the best access to electricity and infrastructure with the lowest costs, taxes, regulatory burden, etc. ➢ SS9: Make sure that each part of the unit fulfills a different, useful or complementary function with an optimal load level. Example for hydroelectric power stations: double-function dam: hydroelectric and hydro-agricultural

4) Technical Contradiction 2 (TC2):

Identifications of the TRIZ modeling parameters:

Concerning the technology and the investment cost, one refers to the transposition described in the first technical contradiction (CT1). On the other hand, pollution or contribution to climate change is by definition constituted by the greenhouse gas emissions of production power station, and therefore of technology. Thus, from the TRIZ point of view, pollution can be assimilated as brightness or clarity of the technology (18), but also as the harmful effect or factor generated by the object (31).

TABLE VIII. PARAMETERS FOR TECHNICAL CONTRADICTION 2 (TC2)

Characteristic to be improved	brilliance or clarity of the technology (18), effect or harmful factor generated by the object (31)
Characteristic that is getting Worse	energy expended by immobile object (20), mass of immobile object (2)

Application of the resolution matrix:

The use of the resolution matrix of the technical contradictions gives the results figured in the following table:

TABLE IX. EXTRACT FROM THE TRIZ MATRIX FOR TC2

Characteristic to be improved \ Characteristic that is getting Worse		Mass of immobile object	Energy spent by immobile object
		2	20
18	brilliance or clarity of technology	2, 35, 32	32, 35, 1, 15
31	effect or harmful factor generated by the object	35, 22, 1, 39	19, 22,18

The matrix shows the achievement of 8 principles of solution out of 40 possible.

TABLE X. SOLUTIONS FOR TC2

Principles of solutions (generic solutions)	⇒ Physical and chemical parameters change of an object (35): three (03) times ⇒ Color change or transparency (32): two (02) times ⇒ Blessing in disguise (22): two (02) times Segmentation (1): two (02) times ⇒ Taking out (02): one (01) time Dynamics (15): one (01) time ⇒ The mechanical vibration (18): one (01) times ⇒ Periodic action (19): one (01) time
Specific solutions (SS) to propose	➢ SS10: Opt for a power station with a high degree of flexibility for power generation (flexible and variable size); ➢ SS11: During the construction and operation phases, change the degree of risk (volatility, reduce variance); ➢ SS12: Promote variable rate and / or low rate borrowing; ➢ SS13: Opt for a payment as a percentage of income; ➢ SS14: Lengthen the payment schedule; ➢ SS15: Keep track of production plans and periodic maintenance of facilities; ➢ SS16: Change the emissivity properties of the technology; ➢ SS17: Empower all actors in the sector: ➢ SS18: Opt for phasing for the installation of power power station: power to install according to the actual demand; ➢ SS19: Opt for co-financing in order to reduce the guarantees as well as to separate the risks related to financing. Example for hydroelectric power stations: double-function dam: hydroelectric and hydro-agricultural

5) Technical Contradiction 3 (TC3):

Identifications of the TRIZ modeling parameters: Concerning the technology and the investment cost, one refers to the transposition described in the first technical contradiction (CT1). On the other hand, from the point of view of TRIZ, the duration of life of a technology / central can be assimilated as being the longevity or durability of a stationary object (16), but also as being reliability or fidelity (27).

TABLE XI. PARAMETERS FOR TECHNICAL CONTRADICTION 3 (TC3)

Characteristic to be improved	longevity or durability of a stationary object (16), reliability or fidelity (27)
Characteristic that is getting worse	energy expended by the stationary object (20), mass of the stationary object (2)

Application of the resolution matrix:

The use of the resolution matrix of the technical contradictions gives the results figured in the following table:

TABLE XII. EXTRACT FROM THE TRIZ MATRIX FOR TC3

Characteristic to be improved \ Characteristic that is getting worse		Mass of immobile object	Energy expended by immobile object
		2	20
16	longevity or durability immobile object	6, 27, 19, 16	
27	Reliability or fidelity	3, 10, 8, 28	36,23

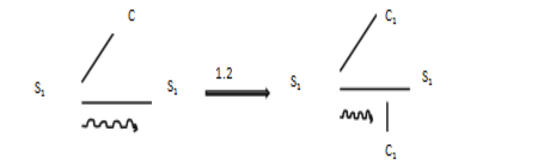
The matrix shows the achievement of 10 possible solution principles out of 40 possible.

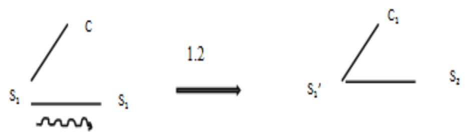
Principles of solutions (generic solutions)	⇒ Redesign or mechanic substitution (28): two (02) times ⇒ Local quality or internal remodeling (03): two (02) times ⇒ The anti-weight (8): one (01) time ⇒ Segmentation (1): one (01) time ⇒ The enslavement (23): one (01) time ⇒ Phase transition (36): one (01) time ⇒ Preliminary action (10): one (01) time ⇒ Dynamics, optimization (15): one (01) time ⇒ Cheap short-lived objects (27): one (01) time
Specific solutions to propose:	➢ SS20: Opt for technologies whose fields of interaction between elements are mainly electric, magnetic or electromagnetic (electronic) fields; ➢ SS21: Ensure that each part of the plant / technical system (technology) operates in the most suitable conditions for its operation: the feasibility studies should be pushed and should incorporate an optimization;

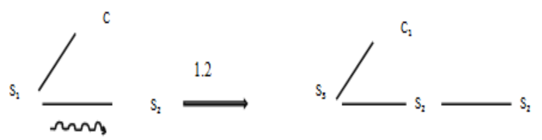
	➢ SS22: Establish an enabling environment for investment: favorable trade laws, minimum taxes, zero corruption, etc. ➢ SS23: Properly choose the location of the power plant and distribution areas in an area with the best access to electricity and infrastructure with the lowest costs, taxes, regulatory burden, etc.(interconnection) ➢ SS24: Make sure that each part of the unit fulfills a different, useful or complementary function with an optimal load level. Example for hydroelectric power stations: double-function dam: hydroelectric and hydro-agricultural

6) Su-Field Model N ° 01:

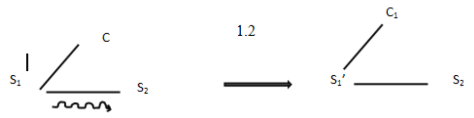
For a first resolution, TRIZ proposes class 1.2. On the other hand, if it is necessary to maintain the links between substances. 1.2.4 or 1.2.5. The resolution possibilities can be represented as follows:







Standards solutions to choose:



SS25: The standard solution proposes the change of property of substance S1 (raw materials) in substance S'1. Practically, this means using cheap local raw materials and / or using available renewable energies.

The synthesis of these specific concepts leads to a solution that could be formulated as follows: "a technology based on an energy mix using local and renewable energy sources implanted in political, commercial and tax environment favorable to an investment and easy to integrate into an interconnected network ".

IV. DISCUSSION

TRIZ refers to a general concept of a generic solution or solution formulated as follows: "a technology with parameter levels: energy source, power output, efficiency, lifetime, pollution and flexibility of use with values (characteristics) in order to meet a cost of electricity production that tends to zero" The first "initial situation analysis" step of the TRIZ approach identified a general concept of solution that answered our research question. At the end of the restriction of the problem situation, the parameters of the ideal technology are identified. This result confirms the analysis of the existing technical system using the first group of Laws of Evolution of Technical Systems (Static Laws), on the systemic production electricity.

Indeed, from the TRIZ point of view, the ideal technology is the technology with which the values of its various parameters lead to reducing the cost of producing electricity by eliminating any compromise. It is in this sense that contradictions have been formulated whose resolution leads to more specific solutions that can be operational. The analysis carried out by C. Hereaux are already pointing towards this level of pragmatism, which according to the expert constitutes a blocking factor for the supply of electricity in African countries, and this through the decisions concerning the technological choice [1]. The generic solutions proposed by the research approach constitute axes for the generation of specific solutions. Focusing on the cost of production, the following concepts have been identified:

In practice, TRIZ is moving towards a technological choice based on an energy mix using local and renewable energy sources implanted in political, commercial and tax environment favorable to an investment, and easy to integrate into an interconnected network.

The analysis steps of TRIZ have made it possible to identify several parameters to consider in finding a solution adapted to the cost of production problem. Contradictions have been identified which, according to this theory, already means solutions while eliminating trade-offs. Indeed, in order to reduce the operating costs, and the specific solutions listed from the approach, a large part proposes the use of local and renewable energy sources in the generation of electricity. This concept converges towards the objective of the theory which is the ideality of the solutions or Final Ideal Result or FIR. On the other hand, this solution also reflects one of TRIZ's foundations in resource management. Practically, even if TRIZ solves the problems with a step of abstraction, it allows keeping a certain level of pragmatism in the choice and the identification of the specific solutions. It should be remembered that the generic solutions from which specific solutions are generated are the result of the scientific procedures of several researchers and which are listed on more than 10,000 patents [9].

Solutions principles such as change of parameters have also been identified in technical, contradictions solving, physical or Su-Field model. In the formulation of the specific solutions, this principle advises towards the consideration of the environments in which develops the technical system or in other term the technology to be implanted for the JIRAMA. These parameters include political, social, fiscal, customs, etc., which will have direct impacts in the implementation of technology. Indeed, as the production of electricity is a rather complex system, a systemic vision of the whole is essential in order to be able to solve the problems and to be able to propose practical recommendations.

The consideration of the existing power station is also noticed in the solutions proposed by the approach. One of the steps that this theory proposes is the determination of adjacent systems. This concept also converges on the search for the level of pragmatism of this methodology. From what follows, the ease of injecting production into the existing network has also been identified from TRIZ. However, this research has focused primarily on technological choice, leaving many avenues for future research.

V. CONCLUSION

Pragmatic and realistic solutions can be implemented to the Malagasy State Owned Company in order to improve its performance and the electricity sector of Madagascar in general. Research and analysis of problems within the company have identified a key performance indicator (KPI) that needs to be improved: the cost of production. It was in this way that this research was conducted.

The TRIZ approach allowed for an in-depth analysis of the situation of JIRAMA while remaining objective in the choices and decisions in the stages of research. Indeed, from TRIZ, many generic and specific solutions have potentialities to reduce the cost of production of JIRAMA. The synthesis of several specific solutions has led to the solution that could be formulated as follows: "A technological choice based on an energy mix using local and renewable energy sources implanted in a political, commercial and tax environment are key to a good investment, and easy to integrate into an interconnected network."

However, the implementation of the solutions requires several technical, commercial, political, fiscal and environmental considerations, in order to ensure the benefits that may ensue. In fact, a systemic vision of the situation is essential for the success of the project in the company JIRAMA. In other words, several factors must be combined in harmony to achieve the objectives.

Certainly, the results of our research did not reach a level of ideality, but could already constitute elements of decisions for the leaders. In addition, the approach has made it possible to identify other avenues of research in the context of improving Madagascar's electricity system.

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