Probing Potential of Knowledge Engineering Support for Electrical Engineers – A Case Study

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Abstract: Because of ever increasing complexity of electrical engineering systems, this is needed to provide supportive guidance to electrical engineers in dealing with increasing complexity of systems. This paper summarizes a case study conducted to assess qualitative benefits of emerging knowledge engineering tool named TRIZ (Theory of inventive problem solving), for the field of electrical engineering. The study considers few key aspects, which proves that knowledge based guidance can facilitate electrical engineers at initial stages of solution hunting and design process. This early conceptual guidance results into reaching more practical innovative solutions with less time and less need of very high expertise in multiple fields. For purpose of this case study, a group of electrical engineers from National Engineering Consultants (NEC) Pakistan were consulted. Engineers involved in discussion presented few common problems which they faced in their field of working. Initial stages TRIZ based conceptual guidance for reaching innovative and practical solutions was explored and feedback of this joint session is summarized in this paper.
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1. Introduction

For engineering systems in industries and the enhancement of their performance, engineers have always been working to find better solutions. Focus of engineers is mostly the technical problems, arising from engineering systems involved in different activities of industrial processes. As a solution, different new technologies have been introduced over the time to replace or enhance less efficient or problematic systems. These new technological inventions are the output of a continuous process starting from a feel of need and originating as a solution in human mind. Engineering is the process of turning those ideas into reality by defining the concepts and implementing those into physical systems/products. This creative act of turning ideas into technological concepts and ultimately into a physical product is called engineering design. Most of the existing inventions/systems are the output of creative human efforts, which either did not exist before or are improvements in some previously existing systems. For reasons, the engineers are known as "problem solvers", who address some need/problem of a current scenario and are supposed to come up with some practical solutions [1].

Electrical (Power Distribution) systems involved in industries are the prime focus of this research. As an output of the problems in Electrical systems, besides different type of equipments/ components damage, one most common result is the loss of energy in systems. Such damage and energy loss make the overall process of industries more expensive in terms of utilities used and costs associated with damages. Resolving the problems arising in engineering systems have been an ongoing challenge for electrical engineers since the systems existed and newer technologies/solutions always have been sought. For this solution hunting, a solution is thought to be the best solution which meets all the requirements and can be delivered within required time while produced with the available resources [2].

In this scenario, at one hand, Engineers as problem solvers are required to bring best solutions simultaneously to meet all requirements and limitations of cost, time and resources. On the other hand, with the technological advances, engineering systems are becoming more complex and difficult to handle. The complexity of Electrical engineering systems and the integration of different technologies (e.g. Electrical devices, Electronic devices, ICT equipment, Automation equipment etc) as part of one engineering system make it very challenging for engineers to understand the root cause of problems and come up with better solutions. Ever increasing technological inclusions e.g. distributed generation of power from multiple resources and need to manage/monitor power consumption smartly for better usage of available power are examples of added complexity and integration of technologies in power systems [3-4]. Much higher expertise and knowledge of multiple fields are required to seek a comprehensive and efficient solution, which ultimately need bigger project teams with higher expertise on behalf of engineers (problem solvers). The literature of research presents different knowledge engineering conventional tools (artificial intelligence), used for helping electrical engineers [5-6]. To reduce this complexity and facilitate Electrical Engineers, TRIZ do offer an efficient set of tools and methods.

Filmore [7], referring to research literature, discussed in his research about key attributes of highly effective engineers and their co-relation with TRIZ tools. It presents how TRIZ tools effectively address and support engineers for all key attributes of being innovative and effective for solution hunting engineering process [7]. Taking these key attributes as our main qualitative functions, following case study is conducted with a group of young electrical engineers from NEC, Pakistan. Young electrical engineers were chosen because of TRIZ's claim for reducing complexity and making solution hunting easy even for engineers with less expertise (young engineers are with less experience as compared to highly experienced professional engineers). The engineers were asked to provide some examples of basic and common electrical problems from their regular field of working. The problems were then analyzed using TRIZ tools jointly by author and electrical engineers from NEC, Pakistan. Feedback of engineers based on key attributes of "Highly effective engineers" referred above was sought and had been summarized in this paper. The discussion shows effectiveness of TRIZ tools for engineering solution seeking process at initial conceptual phase, which helps engineers in finding the right direction during solution hunting process. This results in innovative solutions meeting the requirements and limitations to their best. Feedback of electrical engineers is summarized in perspectives of conceptual guidance for engineers during solution exploring process. This research sought and attempted to answer question, that does systematic stepwise guidance makes the solution thinking process less complex and easier for electrical engineers? Does it open new ways for them to think out of the box? Does the TRIZ make electrical engineers see beyond their personal experience gained so far? Does it remove the fear of looking for unseen and uncertain results? etc.

The group of engineers presented few common problems like voltage depressions mitigation, energy losses at lower load, idle running motors, power factor issues etc. TRIZ tools implementation for solution guidance for all above given common problems were presented and discussed with engineers. For the purpose of explaining the research done for taking engineers' feedback in short way, voltage depression mitigation example is explained in this paper. The paper presents the results of feedback taken after presenting systematic guidance capabilities of TRIZ with all of the examples above. The in depth details of this example are not presented fully here, because those were considered as an output for possible future work of this research and will be presented later in future research documentation. Some of the intermediate stage discussion diagrams are not included here to avoid unnecessary length and to keep the brevity.

Case study – TRIZ implementation for Voltage Dip:

NEC electrical engineers liked to try potential solution guidance of TRIZ for voltage dip problem while focusing on affected performance of MCCs (Motor control centers) in industries. MCCs are responsible for controlling different motors' operations in industries. These MCCs controlled systems often face losses due to voltage dips in supply system of the industrial equipment/MCCs. As a definition Voltage dip is defined by NEMA MG1-16.48 as "the maximum voltage deviation from rated generator output voltage" [8].

Because of voltage depressions/dips (sudden voltage drop) at some unexpected hours in supply line, MCCs cut off power supply to motors as protective measure and this shuts down all operations related to motors. Such shutdowns of operations create loss of energy, time and costs associated to restarting the heavy system again. This interruption is very crucial to those industries where processes need a continuity of system running, because it can result in raw material losses in production lines as well as damages to electronic boards [9]. This problem has been experienced by almost all types of industries because of voltage depressions occurring at supply lines. Our research team (Author and NEC electrical engineers) took voltage dip as one of the examples for research case to explore/prove guidance capabilities of TRIZ for Electrical problems.

To have a clear picture and understanding of the problem, problem definition is sought using TRIZ tools. Using 'TRIZ windows operator' tool for problem definition, initial definition was made as in Figure 1:

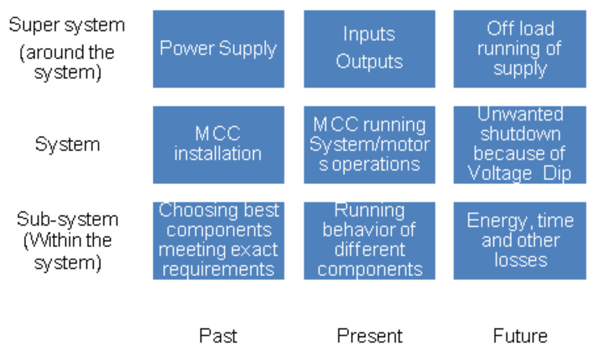

Figure 1. MCC controlled system operations – TRIZ System Operator

As a core aim of solution seeking, It was discussed that voltage depressions at supply lines happen because of different reasons, but engineers want a solution at MCC panels (consumer end), not at power transmission/supply lines. These voltage depressions are of a very short span (usually last for fraction of a second). The protection of system responds to these milliseconds voltage depressions and shut downs the system immediately. Using windows operator to expand the definition further to reach the exact problem, MCC shutdown section was expanded further in depth as shown in Figure 2.

With some further expansions of few targeted windows, point of discussion narrowed towards "relays/protective components detect the voltage depression and cutoff the system operation as protective measures". If we somehow stop protection relays to sense such a milliseconds of voltage depression and at the same time keep the system safe as well, this may solve the problem.

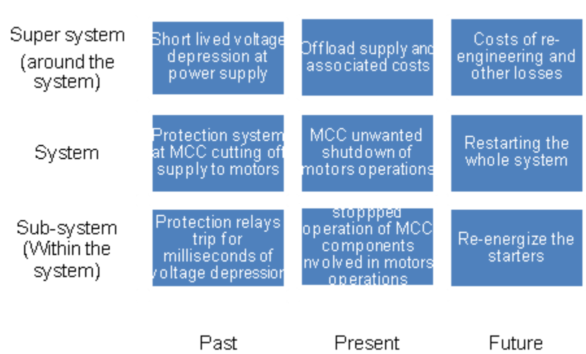

Figure 2. MCC behavior for voltage depression: TRIZ system operator

To see a general overview of internal functions between system components, function analysis tool of TRIZ was tried. In order to show function analysis of working system, a simple function analysis diagram (one of TRIZ tools) was drawn for this operation of protective relays. The basic diagram is shown in Figure 3.

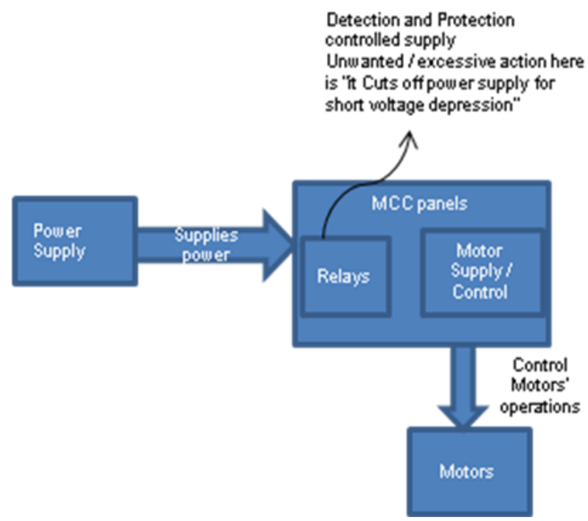

Figure 3. Function analysis diagram of MCC controlled system

The required output as desired by engineers was that, the protection system keeps running for protection of system but shouldn't respond negative to short lived (milliseconds) voltage depressions. It should keep all other protection properties including protection against longer timed lower/higher voltages. For this requirement, in function analysis diagram, the relays' action for short time voltage depression was shown as excessive/undesired action and required solution may seek for removal of this excessive/undesired action.

For finding a possible solution to the problem, which was further understood by zooming into different windows of TRIZ system operator, different tools of TRIZ were consulted and two solution directions were sorted out. Using Contradiction matrix table [10], Reliability of protection system was needed but its harmful effects were supposed to be removed. This was taken that improving feature is "reliability" and worsening feature was "harmful factors". Selection of corresponding row and column from contradiction matrix, intersection cell directed us for TRIZ inventive principles "35, 2, 40, 26". These inventive principles refer to the highest probability solution for our problem. Reading each principle, examples and analyzing our situation, one possible solution came as "35- Parameter changes". This suggests that the parameters of operating the protection relays should be changed so that those relays perform according to requirements. In discussion the question raised was, how to change those parameters is another big challenge to design the complete relay as per requirements. Comparatively, higher expertise and time is needed for solution as against the claim of TRIZ for "fast quality solutions with lower expertise of project team". There should be some other possibilities to this "parameter changes" suggestion that how to do that. Having explored further available TRIZ tools and resources, another viable solution was figured out from "76 standard solutions" of TRIZ [11]. Group 4-3 referred for detection/measurement system suggested enhancement of system. Researchers further consulted on this solution from list of standard solutions in [10]. It guided towards a solution as "if it is not possible to modify the system, then introduce an easily detected additive or object to the external environment". This guideline suggested adding a new device to external environment of relays to enhance the measurement/detection system parameters. This way may help changing the parameters/behavior of overall protection system according to the requirements. After a short technical discussion over suggested possible solution direction by TRIZ, discussion reached a solution of "adding an external object, a device which keeps the voltage level intact for smaller (milliseconds) voltage depression helps in survival of the system running." Furthermore, after this initial direction of looking for possible effective solution, "Ideal final result (IFR)" and "Resources" tools were discussed to bring in further elements of consideration. It was done to seek TRIZ guidance for better suited solution direction with consideration of all possible potential directions and elements.

Ideality is the ultimate stage of any evolution or the ultimate solution to any problem. All systems (products/organizations etc.) move towards ideality over the period of time. Although the ultimate ideality may be unachievable, the measurement of ideality is done by the formula "benefits /(Costs + Harms)" [12]. Increasing ideality means "increase in benefits", "decrease in costs" and "decrease in harms". Definition of IFR acts as a goal and a guide for designer, which prevents him of straying from the superior-solution path [13]. While defining the Ideal system, we keep in mind that, it should have everything positive, good and nice and should not have anything negative, contradictory and undesired. The ideal system should not be ideal only for user or manufacturer, it should be ideal for everyone; user, manufacturer, designing engineer and all. For the voltage dip problem, participants tried to create a list of desired requirements by user, manufacturer, and designer/engineer as follows:

Manufacturer/company wants a solution that is:

- With lower manufacturing costs
- With better performance to win market share
- Giving higher profits with less investment
- Satisfying market needs for long (sustain market share)
- Having no conflicts with Govt. policies

Engineers/designers want a solution that is:

- Innovative
- Better than all current solutions
- Meeting all requirements
- Satisfying customers fully
- Having better and more features
- Having lower costs
- Having simple design with less complexity
- Being more reliable
- Small and cheap to make
- Easy to manufacture, install and maintain
- Never failing with perfect performance
- Robust
- Responding to voltage dip as and when required etc.

Consumer/customer wants a solution that is:

- With the least costs
- Providing perfect protection and system support
- Totally reliable
- One solution for all problems
  Once for always (one time investment for life time output)
- Having desired size (suits the available space)
- Easy to install
- Having simple operation
- Needing no maintenance
- Easy to upgrade
- Having all possible features for today and for future
- Having flexible usage
- Having no losses associated
- Having no environmental issues
- Having no conflicts with Govt. policies

Identification of available resources around any problem is essential for finding good, cost effective, environmentally friendly solutions. Unlike any other problem solving technique the TRIZ definition of a resource is all-encompassing and focuses even on apparently negative or harmful resources. Thinking about symmetry, smell, color or surface finish as resources rather than just things that exist in the system helps you learn how to identify, transform and then use all the resources to focus on cost reduction and produce elegant, clever solutions. As said by Apte [14] "In

TRIZ, a system is considered as a "system of systems" i.e. a "hierarchical system" consisting of super-system, base system and the subsystems. All available resources of super-system, base system and the subsystems are taken as "resources" of the system". Apte [14] quotes the following types of resources for a technical system:

1. Space Resources,
2. Time Resources,
3. System resources,
4. Function Resources**,**
5. Information,
6. Substances,
7. Energy and Field Resources

Altshuller concluded that the progress towards ideality is closely linked to the utilization of available resources [14]. For the case under discussion, beside system components and in-use resources like

- Solution equipment components,
- Machines,
- utilities,
- human resources,

and other sub-system components which were taken as system components by engineers, there were resources available which were pointed out to be considered as resources. Few of those were:

- air,
- humidity,
- sunlight,
- available illumination,
- electric flux,
- atmospheric heat (wire heat, other equipment's exhaust heat)
- neighboring equipment
- existing control machanisms
- feedback data etc.

Adding future direction to considerations was done by explaining "Trends of Engineering system Evolution (TESE)" tool of TRIZ, which explains the current status of existing solutions while suggesting the next phase of possible evolution of these engineering solutions according to TRIZ analysis of "generic evolution patterns of engineering systems". The discussion brought some good assumptions for future direction of desired systems' evolution. Discussion related to the problems considering TRIZ trends of increasing value, completeness, trimming and controllability brought up some good vision of possible modifications which could be sought as part of making successful solution. "S-curve" TRIZ tool was discussed to make consideration of important "main parameters of value (MPVs)" for looking forward to target worthy features, which could be enhanced to make significant improvements and to strive in competitive market [12]. Findings in TESE and S-curve discussion are not detailed here for the purpose of confidentiality of research work and it will be presented along with future work.

After working out with different examples for TRIZ tools implementation, TRIZ systematic and structured guidance for possible electrical engineering related solutions was well appreciated by the group of young electrical engineers involved in research discussion. The feedback related to TRIZ applicability and thinking support of electrical engineers has been summarized in Table 1. The questions were mainly deduced from research work over attributes of effective engineers [7]. Feedback of engineers was summarized in relation with these key attributes, to see if TRIZ application actually enhances/supports these key attributes in engineers and whether they feel guided effectively or not.

Conclusions

The paper summarized potential of TRIZ tools usage for supporting electrical engineers in solution hunting. Young engineers with less experience were chosen to conduct case study, to get feedback and to validate claims of TRIZ for reducing complexity, time and need of expertise. The results demonstrate good qualitative support of TRIZ for electrical engineers' thinking process. Engineers felt like effectively guided towards possible solutions. Systematic and stepwise guidance provided by different TRIZ tools gave a feeling of confidence while looking for unusual/non conventional directions of solution seeking. The feedback of engineers guided by TRIZ application illustrates strong co-relation with key attributes of effective engineers derived from research literature. Overall discussion and workshop session with NEC, Pakistan's electrical engineers provided very positive feedback for acceptance and practicality of TRIZ tools.

Table 1: Summary of Electrical Engineer's feedback for TRIZ guidance potential

Key Questions for Potential TRIZ Guidance	Electrical Engineer's Feedback Summary
Does TRIZ help in seeing the whole of picture rather than parts?	TRIZ definition tools like windows operator helps in zooming into and out of the problem to subsystem and super-system levels. Function analysis gives better picture to see the problem and its' surroundings linked with the problem. Interactions between components and needed/unwanted actions give good picture for considerations to take into account while looking for the improvement of system.
Does TRIZ make engineers think outside the box and beyond one's conventional knowledge?	Definition of problem into contradictions and seeking potential solutions directions from contradiction matrix is a great source of thinking beyond conventional/limited field specific knowledge.
Does TRIZ help using maximum of the resources?	Resources and constraints concept of TRIZ guides to include every possible thing as a potential resource and hence maximize the resources consideration during solution thinking process
Does TRIZ give a feeling for being aware of our assumptions?	Systematic guiding process and developed database of TRIZ potential solutions does give you a better feeling of awareness and confidence about making any decisions towards next step during solution hunting.
Does TRIZ guide towards Breakthrough change?	Concepts of S-curve and MPVs along with resolving contradictions by looking in a broad solution space beyond your conventional field specific knowledge, do give a possibility of making a breakthrough move towards development of new solution to an electrical system problem.
Does TRIZ feel like guiding towards win-win solutions?	If for some electrical system problem, Contradictions Matrix table of TRIZ does resolve contradictions with no compromises to make and ideal final results are met more closely than usual in market, it surely brings some win-win solution output.
Does TRIZ make engineers take risk with a feeling of control over the upcoming unusual solution?	Systematic guiding process and developed database of TRIZ potential solutions for directing the engineers stepwise towards potential innovative solution, does give them better confidence about making any unusual decisions towards solution hunting.
Does TRIZ reduce complexity of solution thinking process?	TRIZ does reduce complexity by in depth problem definition and zooming in and out of the problem by windows operator, function analysis and IFR definitions for all concerned parties.
Does TRIZ provide systematic guidance making it all a stepwise easy to do process?	TRIZ tools do guide systematically and its knowledge base is pretty strong to offer good guidance towards potential solutions direction.
Does the help what TRIZ offers, actually makes a difference for innovative solution hunting systematically?	It positively helps to seek a solution systematically by stepwise guidance towards potential innovations. It opens up broad solution space at the same time narrows down the target thinking area for reducing complexity and increasing focus of electrical engineers. It supports the thinking process by breaking psychological inertia and speeds up solution hunting process by continuous directed guidance.

This positive result opens a new direction of research for further in detail analysis of electrical problems by TRIZ methods, knowledge base and strong toolset. By taking approach of TRIZ philosophy, detailed analysis of problems prevailed in different electrical engineering domains, and shortcomings of their available solutions may result in knowledge based guidance for electrical engineers. It may facilitate and direct them with solution thinking process.

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References

[1] Khandani S., "Engineering Design Process, "IISME/Solectron, 2005.
[2] Dekker D.L., Engineering design processes, problem solving and creativity, Frontiers in Education Conference, Proceedings 1 (1995), 3a5.16-3a5.19.
[3] Mansoor M., Towards A Model/Framework for Optimizing Automated Engineering Systems in Developing Countries. Proceedings of TRIZCON'08 (2008), Kent State University, Ohio, USA.
[4] Anis W.R., Morcos M.M., Electric power quality and artificial intelligence: Applicability and overview. Proc. Large Eng. Syst. Conf. Power Eng., Halifax, NS, Canada, 1998 (1999a)., pp. 107–111.
[5] Sharifi-Tehrani O., Novel hardware-efficient design of LMS-based adaptive FIR filter utilizing finite state machine and block-RAM, Przeglad Elektrotechniczny, 87 (2011), no.7, 240-244.
[6] Drabarek J., Artificial intelligence methods in data protection techniques, Przeglad Elektrotechniczny, 87 (2011), n. 10, 133-135.
[7] Filmore P.R., Developing highly effective engineers:The significance of TRIZ, Proceedings of TRIZCON'08 (2008), Kent State University, Ohio, USA.
[8] Toromontpowersystem. Definition: Voltage Dip (online consultancy notes - last viewed July 29, 2012): (http://www.toromontpowersystems.com).
[9] Tosato F. and Quaia S., Reducing voltage sags through fault current limitation, IEEE Transactions on Power Delivery16(2001), no.1, 12-17.
[10] Mann D., Hands on systematic innovation, (2002), CREAX Press:Belgium.
[11] Barry K., Domb E., Slocum M.S., What is TRIZ?. The TRIZ Journal, Online TRIZ introducoty notes: The TRIZ Journal, (http://www.triz-journal.com). (Last visited July 29, 2012).
[12] Ikovenko S., MyTRIZ workshop Handouts, MyTRIZ workshop 2011, 14-16 Nov, Uniten Malaysia.
[13] Kowalick J., 17 secrets of inventive mind: how to conceive world class products rapidly using TRIZ and other leading edge creative tools, The TRIZ Journal, Online Journal Archives 1996(11), no.b.
Apte P.R., Introduction to TRIZ: Innovative Problem Solving, (http://www.ee.iitb.ac.in/~apte/CV_PRA_TRIZ_INTRO.htm) (Last visited July 29, 2012).

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