Muhammad MANSOOR, Norman MARIUN, Napsiah ISMAIL, Noor Izzri ABDULWAHAB

Faculty of Engineering, University Putra Malaysia (UPM)

Towards Knowledge Engineering Based Guidance for Electrical Engineers

Abstract. *This paper proposes a concept of knowledge engineering based innovative approach for seeking solutions related to electrical engineering systems. The knowledge base approach is discussed for its effectiveness at preliminary stages of solution hunting and solution design, which may reduce the iterations of design process and save time/cost. While referring research literature, this paper builds a hypothesis for novel and efficient usage of knowledge engineering tools for Electrical Engineers. The research seeks development of a methodological tool, which will be generic for aimed sub-sector (e.g. power distribution) of electrical systems. Based on structured innovation approach, this tool will provide conceptual guidance and direction to find solutions in sector specific electrical system problems. This structured approach and electrical engineering focus of the tool will facilitate electrical engineers for reaching practical and effective solutions with less expertise and time.*

Streszczenie. *W artykule zaproponowano zastosowanie metod inżynierii wiedzy do rozwiązywania problemów związanych z systemami elektrycznymi. Pozwala to na ograniczenie liczby iteracji przy projektowaniu i skraca czas projektu. (**Zastosowanie metod inżynierii wiedzy w projektowaniu systemów elektrycznych**)*

Keywords. Electrical systems, Knowledge engineering, Engineering design, TRIZ
Słowa kluczowe: inżynieria wiedzy, projektowanie

Introduction:

If we look around in our surroundings, we see a lot of different engineering systems added in our life over the passage of time. All engineering systems e.g telephone, Televisions, Generators, Vehicles, Aero planes etc, are examples of technological creativity and innovation adding value to human life. These inventions are output of a continuous process starting from a feel of need and originating as a solution idea 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 complete product is called engineering design. Most of the existing inventions/systems are output of creative human efforts which didn't 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 solution. Coming to engineering design problems, there may be more than one possible solution for some problem and engineers are needed to bring up the best feasible solution considering all the requirements of problem [1]. Competitive market, always growing complexity of High-Tech equipment, need of higher quality power for sensitive equipments and integration of diversified technological components in one electrical system is making electrical engineer's solution hunting tougher as ever.

Engineering design:

Engineering Design in its nature is an iterative process [2], as the engineers work towards building a solution concept and implementing the concept as physical system. The most suitable and desired design solution is the one that most completely meets the requirements and can be delivered at right time, within feasible cost and with the available resources.

Engineers need to turn backward and forward again and again to refine and develop the real system for best possible solution according to requirements. During this backward forward process, design activities can be seen as activities based on successive decision making which enables the design process to converge towards a solution. This iterative process consumes time as well as costs for reaching the ultimate desired physical output. A good solution requires a good methodology or process of meeting the design aims, which makes the engineers consider all the requirements and helps in dealing all the obstacles in reaching the best output in "least time" with "least costs", while using "available resources".

There are multiple design methodologies defined by different researchers over the time which vary a little bit in approach of addressing the design problem or steps to converge the activities towards a solution. Out of different methodologies, this research concept shall consider following "kind of generic 5-steps" of engineering design process [1].

1- Define the Problem,
2- Gather Information,
3- Generate Multiple Ideas,
4- Analyze and select a solution,
5- Test and Implement.

Following above generic engineering design process steps, it is proposed to bring a novel approach of incorporating the emerging knowledge engineering methodology TRIZ (The Theory of Inventive Problem solving) with electrical solutions design process. It'll facilitate Electrical Engineers as problem solvers using strong TRIZ knowledge base.

Complexity of Electrical Engineering Systems and TRIZ

As discussed above, at one hand, Engineers as problem solvers are supposed to bring best possible solutions meeting all requirements with least cost, time and resources. On the other hand, with the growing age of technology, engineering systems are becoming more and more complex and difficult to handle. The complexity of Electrical engineering systems and integration of different technologies (e.g. Electrical devices, Electronic devices, ICT equipment, Automation equipment etc) as part of one engineering system makes it very challenging for engineers to understand the root cause of problems and come up with better solutions. Much higher expertise and knowledge of multiple fields are required to seek a comprehensive efficient solution, which ultimately need bigger project teams with higher expertise at behalf of engineers (problem solvers). To reduce this complexity and facilitate Electrical Engineers, TRIZ do offer an efficient set of tools and methods. It doesn't only reduce complexity of problem solving rather it offers systematic guidance for bringing the innovative solutions for the problems.

As discussed in [3], in process of finding solution for an engineering problem, the project team is supposed to tackle a problem which is usually characterized by many requirements and objectives, some of which are conflicting. Often the team has to deal with problems with no known solution. Such a problem is called an inventive problem and may also contain contradictory requirements. To find a successful solution for an inventive problem, Knowledge and creativity are two essential conditions. In real practice often there is a lack of both of these key characteristics. For dealing with complex integrated systems, the project teams are usually consisting of interdisciplinary expertise. But still it is virtually impossible to integrate universal knowledge of all specialized areas into one team. Also research studies have shown that creativity diminishes steadily throughout the work phase of life and people hesitate to be creative, because they fear that they lack the essential skills. The usual human approach towards solving problems is by analogical thinking. That is, we try to relate the problem we are facing to some standard class of problems (analogs) we are familiar with, and for which a known solution exists. If we can draw the right analogy, we can find the right solution. Our knowledge of such analogous problems, however, is the result of our educational, professional, and life experiences. Ideally, all potential directions for solutions should be equally regarded. But as an output of field specific knowledge, expertise and experiences, only solutions derived from one's personal knowledge and familiarity are considered while the consideration of alternative technologies (the innovative thinking) to develop new concepts is ignored. This results in what is called psychological inertia, which lacks randomness and leads only into those areas of personal experience. For electrical engineering solutions, it would be a decisive advantage if the team had an extensive knowledge base and was capable of generating innovative concepts purposefully and systematically, rather than more or less at random [3]-[4].

TRIZ brings the concept of step wise systematic innovation while addressing conflicting requirements, technical contradictions, requirement of multidisciplinary expertise, hesitancy towards being creative, psychological inertia problems of project team through its systematic innovation methods and wide range of strong tools. TRIZ expands the knowledge horizon of the developer by using a scientific-engineering knowledge base and supports the user systematically throughout the process of creative problem solving. The method ensures an effective and efficient search for innovative solutions, focusing on the so-called Ideal Final Result. It limits the search field considerably, but fosters creativity within that search field. [4].

Research literature provides some good examples where different Knowledge Engineering tools of artificial intelligence as well as TRIZ have been used effectively for problem solving of electrical and related engineering domains e.g. novel electrical devices development, innovative approach towards product and process designs, Electrical energy saving, quality planning and energy conservation/saving practices [7-14].

Proposed research development:

During the solution design, while pursuing the Engineering Design process, considering the defined problem, its' core reasons and surrounding elements/important factors to keep in view, a conceptual design is sought for the solution. This conceptual design can be considered as some kind of qualitative (non-quantitative) design at initial design stage. Usually more than one solution come up for some specific problem which is to be analyzed against the requirements and best suitable solution is chosen for implementation. The detailed design with specific parameters' quantitative evaluation and implementation follows the non-quantitative/conceptual design stage. The process progresses through these stages in an iterative manner. At each of these stages the product design exists in distinct level of available information which is called a "design state" [5]. The complete design process is a kind of process which is based on successive decision making, this successive decision making ultimately leads towards a solution.

This research proposes that at initial design process activities (which can be grouped as conceptual design phase), incorporating TRIZ tools will help electrical engineers breaking the mindset, while bringing more practical and innovative ideas. This integration of TRIZ at conceptual design phase will ultimately make engineers reach a good conceptual design systematically. This will be leading towards an innovative and practical solution by helping them make the "right decisions at every successive stage/activity" hence saving time, cost and unnecessary iterations. Taking help with TRIZ methodology at initial design stages is like "sharpening the axe before cutting the tree". TRIZ sharpens your axe the best and it takes very little effort to cut the tree (find the suitable innovative and practical solution).

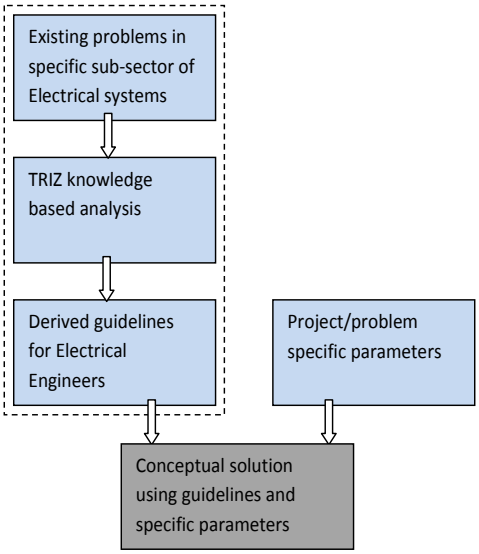

Fig. 1. Proposed TRIZ analysis for Electrical Engineering Problems

The proposed development further aims at simplifying Electrical Engineering solutions' design process and leading the engineers towards "potential future" innovative solutions. To cater deficiencies and limitations in today's Electrical systems and to guide Electrical engineers towards future solutions, this research proposes that analysis of current electrical problems (e.g. power distribution sector) and available solutions by TRIZ knowledge base toolset will result in sector specific guidelines for future solutions (As depicted in Fig. 1). TRIZ concepts of "Trends of engineering system evolution" and "S-curve analysis" will result in conceptual framework for looking forward to right future innovation. It will help in breaking limitations and contradictions existing in current available solutions related to Electrical engineering problems. The proposed analysis of sector specific Electrical Engineering problems along with their current available solutions by tools and knowledge base of TRIZ will simplify problem identification, solution exploration and conceptual design for Electrical engineers. Problem definition tools of TRIZ (system operator, Function Analysis, Ideal Final result (IFR) etc) have potential for reaching the right problem and root cause for that problem

which should be addressed. IFR helps seeing whole of the picture and directs towards bringing an optimum performance solution. Problem solving tools of TRIZ (Contradiction Matrix, Inventive principles, standard solutions, S-field analysis etc), lead towards breaking mindsets and exploring the solution space beyond field specific expertise of solution seekers.

S-curve, Trends of evolution can assess the current status and foresee the conceptual direction for potential future solutions related to current Electrical engineering problems [6]. This all helps in building the right conceptual design before entering into quantitative design phase where parameters quantifications, testing and implementation can cost a lot more time if the conceptual stage doesn't bring a strong output. Improvements needing iteration/repetition for design activities can consume unnecessary time and funds, if the initial solution sought is having deficiencies. Furthermore, this comprehensive analysis of sector specific problems in particular Electrical engineering domain, may work as "generic guideline" for conceptual stage design process for that sector specific problems. This will result in ease for Electrical engineers working in that specific domain of electrical engineering, hunting the needed solutions with generic guidance extracted and modified from TRIZ knowledge base. After successful outcome of one sector, the research may further be extended to different Electrical Engineering domains, producing more comprehensive and generic guidelines for electrical engineers in future. TRIZ guidance domain for Electrical Engineers may be depicted as in Fig. 2. The figure shows different TRIZ tools which can help at referred generic design stages. The proposed research output will be a set of guidelines which will take electrical engineers through initial design stages for reaching an innovative and effective conceptual design.

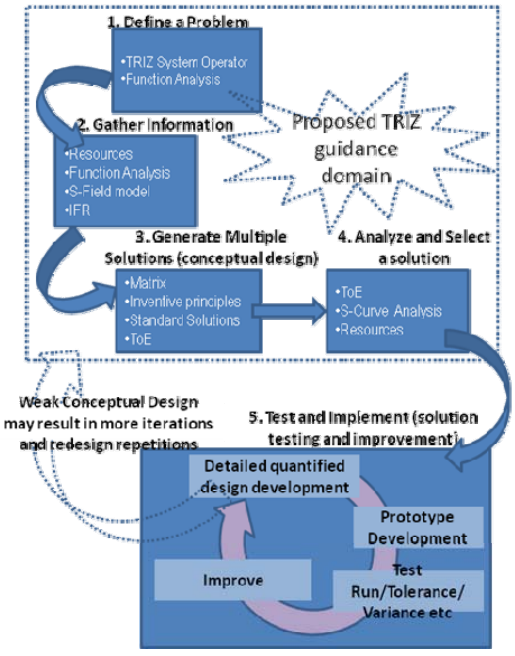

Fig. 2. TRIZ guidance domain for Electrical Engineering solution design

Conclusions

The emerging Knowledge Engineering tool TRIZ has potential to produce good qualitative improvements to electrical engineering solution design process. It can reduce complexity of solution seeking process for electrical engineers, guiding them to innovative and effective solutions in a structured systematic way. By reducing complexity, breaking psychological inertia for innovative thinking and expanding solution search space of engineers across their own field of expertise, it guides engineers to make right decision and reach an effective conceptual design before entering into quantitative phase. Development of sector specific guidelines by analysis of electrical engineering 'sector specific' problems using TRIZ toolset, will lead towards more focused, more simplified, faster results oriented, innovative and systematic guidelines pertinent to a specific electrical engineering segment. After successful outcome of one sector, the research may further be extended to different electrical engineering domains, producing more comprehensive and generic guidelines for electrical engineers in future.

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***Authors**: Mr Muhammad Mansoor, Department of Electrical & Electronics Engineering, Faculty of Engineering, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia,Email: mansoor.upm@gmail.com; Prof Dr. Norman Mariun, Department of Electrical & Electronics Engineering, Faculty of Engineering, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia,Email: norman@eng.upm.edu.my (Corresponding Author) ;Prof Dr Napsiah Ismail, Department of Mechanical & Manufacturing Engineering, Faculty of Engineering, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia, Email: napsiah@eng.upm.edu.my; Dr Noor Izzri AbdulWahab, Department of Electrical & Electronics Engineering, Faculty of Engineering, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia, Email: izzri@eng.upm.edu.my*