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Application of Knowledge Engineering methods in Electrical Engineering - A hypothesis for potential TRIZ usage

Abstract – Increasing need of innovative solutions for existing engineering systems has brought interest of engineers towards systematic innovation. While highlighting effective use of Artificial intelligence (AI) tools, the potential for emerging approach of knowledge engineering- Theory of inventive problem solving (TRIZ) has been discussed in this paper. This review seeks to affirm the potential application of knowledge engineering emerging tools, for effective solution hunting space in electrical engineering problems. An extensive collection of literature has been covered to develop the hypothesis about benefits of systematic innovation for electrical engineers. Merits of innovative and systematic approach over traditional solution approach in existing industries are highlighted through reference of scientific literature.

*Streszczenie. W artykule omówiono metodę TRIZ służącą do tworzenia nowych innowacyjnych pomysłów i rozwiązywania problemów. Skupiono się na zastosowaniu metody w systemach elektrotechnicznych. Przedstawiono, popartą literaturą analizę pozytywnych wpływów metody TRIZ na elektrotechnikę. Wykazano przewagę innowatyki i systematyki nad podejściem tradycyjnym w przemyśle. (**Aplikacja metod inżynierii wiedzy w elektrotechnice – hipoteza dla potencjalnego zastosowania metody TRIZ**).*

Keywords. knowledge engineering, TRIZ, Innovation, Electrical system problems
Słowa kluczowe: inżynieria wiedzy, TRIZ, innowacja, problemy systemów elektrycznych.

Introduction

The complexity of engineering systems as well as need of expertise in multiple fields for dealing with problems has been increasing with passage of time. This complex nature of upcoming problems and required solutions has brought a need for systematic and innovative ways for finding solutions. Researchers have been working to build methods and tools to help engineers in getting the effective solutions with less efforts and time. Knowledge engineering tools like Theory of inventive problem solving (TRIZ), Fuzzy logic (FL), Adaptive Fuzzy logic (AFL), Genetic Algorithms (GAs), Expert Systems (ESs), Artificial Neural Networks (ANNs) have grown over the time for seeking best and effective ways for helping engineers in creating better design and planning. The growing field of knowledge engineering provides very effective tools and methods to deal with difficulties of engineers in facing this growing complex situation. For this review, present knowledge engineering definition is taken from Fensel and Siorpaes as "knowledge engineering is a process of eliciting , structuring, formalizing, operationalizing information and knowledge involved in knowledge intensive problem domain". [1]-[13].

In recent past, different applications of knowledge engineering methods, tools and systematic creativity approach have been documented extensively in research literature. The areas addressed by different creative methods include: product design, process design, solution design, engineering problem identification, operations, safety developments, control and monitoring, supply chain management, human resource development (training/learning) [1]-[4], [8]-[10], [14]-[27]. For the core aim of this literature review, beside other applications in engineering field, focus is kept towards problems in Electrical engineering and related systems. From Electrical engineering point of view major areas addressed in literature include: power system analysis, load forecasting, system stability, fault diagnosis, system stability, planning, generation and distribution scheduling, system control, system security/protection, machines, drives and power electronics etc [26], [28]-[33]. For purpose of classification, problems in Electrical systems involving industries are classified as technical problems (core engineering problems) and non-technical problems (Management, Planning, Human Resource etc.). To deal with growing complexity of problems in an engineering organization, high expertise are needed not in one area but in different areas like e.g., electrical equipments, electronics equipments, energy efficiency, signal processing, electrical safety, ICT applications, management, forecasting, organizational/corporate culture and human factors. This challenge of very broad range of expertise makes it quite difficult to reach an effective solution while considering all domains at once [10]-[11], [34]. In past years, different creative techniques like brain storming, heuristics, parallel thinking, lateral thinking, synectics etc. have been in practice over the past. Development in systematic creativity approach in recent years have made a breakthrough in this field and made it possible for engineers to find best practical solutions with comparatively less expertise in different fields simultaneously [4], [14], [17], [35]-[40].

While highlighting the strong knowledge engineering methods classified as Artificial Intelligence tools, discussion also focuses towards relatively new development of creative methodology - Theory of inventive problem solving (TRIZ) in knowledge engineering domain. Other statistical and qualitative techniques like Taguchi methods, Six sigma, Quality function design (QFD), Axiomatic design (AD) etc. used for engineering design and solution finding are also reviewed in reference to TRIZ integration with these techniques [21], [35], [41]-[43]. This study reviews wide range of cases where TRIZ actually proved as a vital tool for engineers in finding effective solutions. Documented case studies show that TRIZ approach is faster as compared to traditional approaches and guide towards effective solutions with less expertise at behalf of solution seekers [1], [4], [17]-[18], [44]. Documented literature in this paper shows that with all these new developments, field of knowledge engineering is well accepted as one of the new alternative approaches towards engineering solutions. This review affirms capabilities of knowledge engineering tools for making effective solution hunting less complex and easy going for engineers.

Electrical Engineering Problems in Industries and Energy Efficiency

Energy is an essential input for today's social, industrial and other domestic life sectors. After the recent growth of industries and agriculture activities, the energy demand has increased heavily. This significant increase in demand of energy can be observed specially in growing economies. In a time when fuel shortages, global warming and alternate energy resources are becoming the main topics of

discussions, efficient use of energy has gained high importance. Most of the equipment in industries and different appliances used domestically operate with electrical power input. Hence, efficiency of electrical power technology is gaining high importance in today's world. Energy efficiency slogans like "Go green", "Green Grid", "climate saver computing initiative (CSCI)" and other efforts of reducing energy waste becoming topics of discussions. Shortage of energy resources is resulting in higher prices of energy utilities, hence bringing new competition in market for energy efficient products to reduce operating costs for customers. To mitigate the effects of resources shortage, research on topics like alternative energy resources, renewable energy resources, energy management systems and demand side management (DSM) are gaining importance [31], [33], [45]-[57].

Addressing problems in industrial electrical systems, technical problems existing in Power systems are caused mainly because of power quality issues. Hence the power quality field has got increasing interest among researchers. A power quality problem could be any power problem in voltage, current, or frequency that results in failure or undesired behavior of equipment [8], [30], [32], [58]-[60]. Major classification of power quality disturbances in electrical power systems are transients, interruptions, sag/under voltage, swell/over voltage, wave form distortions, voltage fluctuations, frequency variations. Factors effecting the quality of power include number of power stages, long range of AC lines, High voltage distribution, voltage regulation, load profile, redundant power systems, increasing use of semiconductor devices, digital power management, motors etc. Poor power quality results in problems like equipment damage, process hindrance, energy loss, material loss etc. Such damages and losses make the overall process of industries more expensive in terms of utilities used, time wasted and costs associated with damages [8], [29]-[30], [32], [58], [60]-[61].

TRIZ – An Emerging Knowledge Engineering Tool

"TRIZ" is the acronym for "Theory of Inventive Problem Solving" in Russian. Developed by Genrich Altshuller and his colleagues, is now being developed and practiced throughout the world. Many companies are using TRIZ on many levels to solve real, practical everyday problems and to develop strategies for the future of technology. TRIZ is a methodology, tool set, knowledge base, and model-based technology for generating innovative ideas and solutions for problem solving. TRIZ provides tools and methods for use in problem formulation, system analysis, failure analysis, and patterns of system evolution (both 'as-is' and 'could be'). TRIZ, in contrast to techniques such as heuristics and brainstorming (which is based on random idea generation), aims to create a systematic approach to the invention of new systems, and the refinement of old systems. The innovative solutions are the breakthroughs towards better efficient solutions and better output [4], [9]-[10], [15], [18], [37], [62]-[66].

Concept of innovations has always been there but introduction of systematic innovation is recent development as the research on knowledge engineering areas grew. The desire to innovate is integral to the human condition and brings the push towards change and invention. 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. For improvement of an engineering system, 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. TRIZ effectively deals with these 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. TRIZ has evolved rapidly since last one decade since when it reached west. Algorithm for inventive problem solving (ARIZ), Anticipatory Failure Determination (AFD), Directed Product Evolution (DPE), integration of Bright process, Ideation TRIZ etc are the developments over the time, which evolved TRIZ from a traditional set of tools to more comprehensive and effective methodology [4], [10]-[11], [18], [67]-[69].

Application of Knowledge Engineering – For Electrical Systems In Industries
A-Technical Problems (Core Engineering Problems)

Application of knowledge engineering tools in engineering problems has been increasing rapidly over the recent past. Creative methods of knowledge engineering domain TRIZ and Artificial intelligence (AI) have been used to address different engineering problems along with other statistical and qualitative tools. Typically different AI tools like Fuzzy logic (FL), Adaptive Fuzzy Logic (AFL), Expert systems (ESs), Genetic algorithms (GAs) and Artificial neural networks (ANNs) have been applied to a lot of problems related to electric power [8], [25]-[26], [28], [70]-[72].

FL and AFL have been applied to different electric power research domains like diagnosing power quality problems, classifying disturbances, adaptive metering of 'power, voltage and current', managing data, assisting the power quality professionals, abnormal electrical operations, active power filters for power quality improvement, estimating power quality indices, allocating capacitor banks, automating system VAR control for improved voltage stability and predicting system abnormal operations [27], [73-[79]. ESs have been applied for classifying distorted voltage and current waveforms, analyzing harmonics using expert system technology, procedures for power quality problem solving, automating fault analysis and fault location, identifying power quality events through a scalable system, managing power quality data and educating personnel involved with power quality [27], [74]-[76]. Research documented related to ANNs application in electric power problems is identifying power quality events from non-power quality ones, modeling the patterns of harmonic production from individual fluorescent lighting systems, estimating harmonic distortions and power quality in power networks, identifying high-impedance fault, active power line conditioner, unified power quality conditioner, developing a screening tool for the power system engineer to use in addressing power quality issues [8], [25]-[27], [80]-[81]. Research addressing electric power issues considering Genetic Algorithms application is documented for problems like minimizing maintenance cost, Optimum selection of lighting technologies, voltage sag mitigation, optimal capacitor allocation and energy loss computation, adaptive metering to optimize sampling rates is also reported [82]-[84].

Beside above mentioned applications some general research documented of AI application in electric power related domains is discussing the potential of applying AI

techniques in power quality, preventive security, substation supervision and diagnosis system for a power grid using AI tools, integrating AI and advanced communication technologies in substation intelligent electronic devices (IED) [25]-[26], [70], [85]-[86].

Different documented applications of TRIZ to electrical and related engineering domains referred for this literature review are novel electrical devices development, innovative approach towards product and process designs, transformer-type fault current limiter development, Electrical energy saving, quality planning and energy conservation/saving practices [1], [16], [18]-[23], [41], [87]-[90].

B-Non-Technical Problems (Administrative and Human Factor)

Knowledge engineering applications are not only limited to technical side of engineering but also applicable equally to management, planning and human factor domains involved in industrial engineering setups. Creative tools of knowledge management including AI tools and TRIZ tools have proven a strong capability to come up with quality system development as well as bringing the innovation in an existing system. Considering social aspects involved in an organization, science has always been trying to figure out answers regarding human brain and behavior for improving performance [6], [91]-[93]. For addressing the wholesome picture of some industry, these efforts have evolved the fields like mind sciences and knowledge engineering in recent years. Artificial Intelligence techniques trying to mimic human brain like behavior for dealing with scientific as well as social aspects. TRIZ has been documented in recent researches over breaking mindsets for innovative approach, developing highly effective engineers, safety improvements, Green services, technology forecasting, quality planning etc. The core TRIZ hypothesis that "Patterns of technical evolution were repeated across industries and sciences" and that, "a solution theory should be familiar enough to inventors by following the general approach to problem solving" gives a broader horizon to look for solutions while using TRIZ tools. The TRIZ tools help exploring the knowledge/solution space in multiple directions with less expertise in multiple fields. TRIZ has been documented in literature for facilitating engineering education and developing effective engineers [11], [17], [22]-[24], [69], [94]-[99].

Conclusions

Field of Knowledge engineering has gained importance as a new alternative approach for engineering solutions. Creative methods of knowledge engineering have been extensively used in engineering solutions in recent past. Literature review shows that different tools like FL, AFL, Expert systems, Genetic Algorithms have been used extensively by researchers for addressing problems in electric power engineering. Although the emerging knowledge engineering tool TRIZ and its application to technical engineering issues has been documented comparatively less than AI applications, the literature review shows strong potential of TRIZ tools application and use of TRIZ innovative approach for electrical engineering solutions. Most of the TRIZ developments are recent and its successful application to different engineering problems shows its capabilities of application to all engineering domains whether singularly or with integration to some other AI or statistical tools like Six Sigma and Taguchi methods. Some software versions of TRIZ toolsets are also available which are mainly interactive and automated software version of classical TRIZ approach, helping engineers for solution seeking through general methodology approach and toolset. TRIZ literature shows that it has been

successfully used to address different domains/nature of problems like technical problems, human factors involvement, planning and management practices. This multidirectional application of TRIZ methodology opens up a room for development of some sector specific comprehensive guidance tool. This will be valuable in today's ever increasing complex situation for engineers, where engineers have to analyze problems in technical systems which can be involving technical and non-technical multidirectional aspects together. In literature, few examples for classical TRIZ methodology toolset applications have been created from electrical engineering related problems. Utilizing TRIZ concepts of root cause analysis, core problem identification, contradiction resolution, ideality and generic patterns/trends of engineering system evolution, the analysis of specific sector related core technical problems will generate a set of generic guidelines/steps for providing systematic guidance to engineers towards innovative solutions. Further enhancement of sector specific guidance tool can be done by involving core non-technical factors along with technical ones, to make effective assessment of multidimensional (technical and non-technical) factors involved in a comprehensive solution. In situations where the knowledge of multiple domains is required for effective comprehensive solutions, TRIZ approach helps engineers for exploring practically effective solutions.

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