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Knowledge Based Model for Power Transformer Life Cycle Management Using Knowledge Engineering

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***Abstract*—**Under the limitation of investment budget, a utility company is required to maximize the utilization of their existing assets during their life cycle satisfying both engineering and financial requirements. However, utility does not have knowledge about the status of each asset in the portfolio neither in terms of technical nor financial values. This paper presents a knowledge based model for the utility companies in order to make an optimal decision on power transformer with their utilization. CommonKADS methodology, a structured development for knowledge and expertise representation, is utilized for designing and developing knowledge based model. A case study of One MVA power transformer of Nepal Electricity Authority is presented. The results show that the reusable knowledge can be categorized, modeled and utilized within the utility company using the proposed methodologies. Moreover, the results depict that utility company can achieve both engineering and financial benefits from its utilization.

***Keywords*—**CommonKADS, Knowledge Engineering, Life Cycle Management, Power Transformer.

I. Introduction

Asset management is the systematic and coordinated activities and practices to optimally manage their assets, and their associated performance, risks and expenditures over their life cycle attaining their organizational strategic plan [1], [2]. However, utility's portfolio comprises of a very large and diversified group of assets resulting in difficulty to manage their assets systematically. Therefore, effective asset management is inevitable to the utility from both financial and technical aspects.

The management and decision making activities of the power transformer operating in a power system are based on the normal load growth with some certain degree of reserved capacity. However, in reality the actual load profile does not always follow this designed load due to unexpected penetration. Then, the load violation will occur at some points during the life cycle of power transformer under which the Utility is required to make strategic decision. In addition, they do not have knowledge about the status of each asset in the portfolio in terms of its technical and financial values. Thus, the decisions were mainly focused on the cheapest price of any assets available in the market without any consideration to investment budget limitation thinking only of the technical aspects rather than financial aspects [3] - [5]. Consequently, the decision becomes infeasible from the financial perspective. In this context, utility must make optimal decision on power transformer considering both financial and technical constraints

The engineering and financial requirements can be fulfilled with the utilization of reusable knowledge embedded within power transformer over its life cycle. However, the available knowledge is unstructured and often in tacit form to be utilized. Hence, this paper is aimed to offer Knowledge Engineering and Management framework to develop knowledge based model for an effective life cycle assessment of power transformer in order to maximize its utilization during its life cycle.

The rest of this paper is organized as follows: Section II presents Knowledge Engineering methodologies and discusses CommonKADS Model Suite. In Section III, the hidden knowledge of power transformer is described briefly. The methodology for constructing the knowledge based model is shown in Section IV. Finally, results and conclusion are given in section V and VI respectively.

II. Knowledge Engineering

Knowledge Engineering (KE) is not simply a means of extracting the knowledge from the expert. It now includes methods and techniques for knowledge acquisition, modeling, representation and utilizing [6]. The development of knowledge based model considers the knowledge modeling as a main activity.

A. Knowledge Engineering Methodologies

CommonKADS [6], SPEDE [7], MIKE [8], MOKA [9] and others are widely used KE methodologies and they are based on SE modeling notations. Models are used to capture the important features of a real system parts in order to understand and manage them easily. They are important to understand the working procedures within a knowledge based system [10].The conceptual models of knowledge intensive tasks are constructed using modeling process. The knowledge modeling is important in knowledge management. Understanding the source of knowledge, the inputs and outputs, the flow of knowledge and the dependents are necessary to model the knowledge [11]. CommonKADS is the most suitable technique that can be considered a knowledge engineering methodology because of having the following features such as

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object oriented approach, platform independent, hybrid approach and documentation and CommonKADS has been widely been applied in different domain such as medical, legal, engineering, business and social sciences [12].

B. CommonKADS

It is the de facto standard for knowledge modeling [6]. It support structured knowledge engineering techniques. The methodology explains principles, techniques, methods and document structure to support the construction of knowledge based model in three stages; context level, concept level and artifact level.

The knowledge model specifies the knowledge and reasoning requirements of the perspective system. It is a tool to clarify the structure of a knowledge- intensive information-processing task. It provides a specification of the data and knowledge structures needed for the application. The construction of a knowledge model consists of three knowledge categories; task knowledge, inference knowledge and domain knowledge. Each knowledge category has its own components to construct model. The details of CommonKADS can be found in [6].

III. Hidden Knowledge Of Power Transformer

The hidden knowledge is the tacit knowledge possessed in knowledge workers or engineers who have been operating on the power transformers. It can also be available within the documents of power transformer. Life cycle phases of asset comprise of acquisition, utilization and disposal phase [13]. The life cycle phases of power transformer are shown in fig. 1. There are different major events or activities occurred in the life cycle of power transformer which evaluates its life cycle cost.

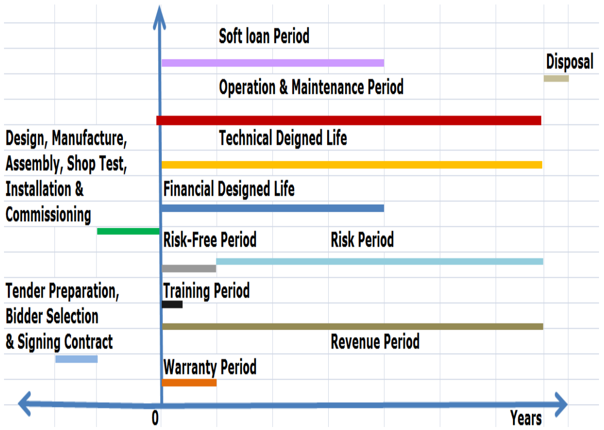

Fig. 1 Life Cycle Phases of Power Transformer [14]

The hidden knowledge is identified with the construction of life cycle of power transformer. The cost associated with the hidden knowledge is determined with interviewing the senior engineers of contractor and is verified with the experts from the manufacturer of power transformer.

Engineering Knowledge: This is the knowledge required for understanding the detail design specifications of power transformer during manufacturing process including drawings, testing reports, etc. It is utilized in the existing power transformer or new transformer during relocation or procurement, and to determine designed safety margin in order to operate further beyond its financial designed life. This is located on the head of manufacturer's experts and on the documents.

EC = function (Design drawings, General lay out drawings, Testing reports) (1)

Transportation Knowledge: It contains dispatch, receiving on site and handling knowledge. This knowledge is needed before installing the existing or new power transformer on the network. It is on the supervisor's head and inside the instruction manual.

TC = function (Freight Charges, Custom Clearance, Crain Charge, Supervisor cost per day, etc.) (2)

Installation Knowledge: Knowledge of location and mounting, site arrangement, erection, testing, oil filling, etc. are required for installation. The supervisor is needed for the proper supervision of installation process. This knowledge can be achieved through the supervisor and installation manual provided by the contractor.

IC = function (Supervisor cost/day * Installation Duration, Erection Cost, Labor Cost, Testing equipments, etc.) (3)

Commissioning Knowledge: This knowledge includes the concept of energizing, measurements and observations, etc; It is embedded within the supervisor and instruction document.

CC=function (Supervisor cost/day * Commissioning duration, Testing equipments, Labor Cost, Accessories, etc.) (4)

Operation and Maintenance Setup: It provides the complete guidelines, procedures and methods to do proper operations and maintenance of power transformer as well as safety precautions in the written form.

Corrective Maintenance Learning: This is the knowledge required for the operation and maintenance workers to diagnose and investigate the failure of power transformer during operation. It is learnt with the help of operation and maintenance expert during acquisition phase.

Preventive Maintenance Learning: It includes the learning of regular inspection, testing and reconditioning of power transformer ensuring correct operation. The operation and maintenance workers can learn from the operation and maintenance expert.

Visual Inspection Learning: This learning provides the knowledge about internal and physical inspections of power transformer periodically to the operation and maintenance workers. They can learn from the operation and maintenance expert of the contractor.

Planning Knowledge: This knowledge includes the concept of design specifications, tender preparation and bidding selection. It is needed at the time of procurement of power transformer. This knowledge can be gained through the expert's of planning and operation department of substation.

Training Knowledge: This knowledge is required to train operation and maintenance workers to become familiarize with the operating and maintenance, safety and protection aspects of power transformer in every five years. This can be achieved from supervisor/or trainer of contractor.

$$TrC = \text{Supervisor cost per day} * \text{Training duration} \quad (5)$$

The total cost incurred at the year of power transformer acquisition is given below when the hidden knowledge is not utilized:

$$TC = PC + EC + TC + IC + CC + TrC + OMSC + VIL + PML + CML \quad (6)$$

Similarly, the total operating cost of power transformer is determined by the following equation in case of no utilization of hidden knowledge during operating and maintenance stage:

$$TC = TrC + OC + VIL + PML + CML \quad (7)$$

The utility company can have a net savings of around 35.25% of its asset price with the fully utilization of hidden knowledge [14] because the knowledge embedded within the documents and experts such as drawings, testing reports, supervisors, etc. can be reused. In addition, it can provide technical knowledge of the power transformer for maintaining its engineering requirements. Hence, the above mentioned knowledge can be utilized within the power utility by constructing the knowledge based model.

IV. Knowledge Based Model Construction

The knowledge engineering is used to capture, model and utilize the knowledge systematically. CommonKADS (Common Knowledge Acquisition and Design System) is adopted because it supports structured knowledge engineering techniques. Besides, it offers some inference useful templates to create knowledge framework and these templates provide useful guidelines for interviewing, analyzing, modeling and utilizing knowledge [6], [12].The construction of knowledge based model is divided into three levels; organization model (context level), knowledge model and key ontology (concept level) and support tacit knowledge (artifact level). Firstly, the overall tasks associated with the life cycle cost of power transformer, referred to hidden knowledge, are presented in the organization model. Secondly, knowledge model and key ontology diagram are used for conceptualizing on the particular task. Finally, support tacit knowledge diagram explains the problem solving structure of all existing tasks. The knowledge elicitation processes is completed with the use of available knowledge templates shown in table I, table II and table III and organization model worksheets. It is represented with knowledge map (K-Map).

In addition, the hidden knowledge presented in the knowledge based model will become obsolete due to the advancement of technologies and practices. Hence, an expert is hired to update and maintain the knowledge based model in every five years in order to practice of obsolescence rate.

A. The Context Level

It includes CommonKADS Organization Model to discover problems and opportunities for knowledge based model. It can be constructed using organization model worksheets. This level provides the scope and crystal view of power transformer hidden knowledge implementation.

B. The Concept Level

This level conceptualizes the hidden knowledge of power transformer. CommonKADS Knowledge Model provides the types and structures of the knowledge used in performing a task in detail.

TABLE I
CommonKADS Model Suite

Model	Composition of Model
Knowledge Model	Task Knowledge (Goal and Sub Goal)
	Inference Knowledge (Reasoning)
	Domain Knowledge (Specification)

The key ontology template [15] also describes various sources from which the knowledge is elicited and formalized in terms of ontology.

TABLE II
Key Ontology Template

Composition of Model	
Who	Experts
	Knowledge Workers
	Community of Practice
	Knowledge Portfolio
Document	Manual
	Book
	Standards
	Working Procedures
	Drawings
	Control/Protection/Information System
	Checked Sheets
	Measuring Point List
	Cases
Information	Updated Information
	Link to Database
Abstract	The Short Description of Work

C. The Artifact Level

This last level contains support tacit model. The algorithms and tools required for implementation are included in this level. It describes the structure of the software system needed to implement the knowledge and communication models. The table III [15] depicts the details of support tacit knowledge.

TABLE III
SUPPORT TACIT KNOWLEDGE

Model	Composition of Model
Support Tacit Knowledge	Precautions/Cautions
	Advantages/Disadvantages/Alternatives
	Methods/Strategy to Solve the Problem/Control /Maximize/Minimize/Optimize
	Condition/Criteria
	Guideline Techniques/Recommendation /Ensure
	Requirements/Objectives/Needs
	Limitations
	Assumptions
	Examples

V. RESULTS AND DISCUSSION

Nepal Electricity Authority is used for a case study to confirm the applicability and benefits of using the hidden knowledge embedded within one MVA power transformer in the organizational wide context with the use of CommonKADS methodology.

The knowledge elicitation is done by using structured interview with senior operation and maintenance engineers from Grid Operation Department of NEA, Manufacturer and Supplier of power transformer. Moreover, the knowledge is captured from the documents related to the life cycle cost of power transformer. Hence, the knowledge both in tacit and explicit forms are gathered and made more explicit within the power utility. The results show that the hidden knowledge implementation of power transformer consists of 125 diagrams in total where 49 diagrams of context level, 38 diagrams of conceptual Level and 38 diagrams of artifact level.

TABLE IV
IDENTIFYING KNOWLEDGE ORIENTED PROBLEMS AND OPPORTUNITIES

Organization Model	Problems and Opportunities Worksheet OM-1
Problems and Opportunities	• Not fully utilization of PT without the utilization of hidden knowledge. • Unstructured and in tacit form
Organizational Context	• Enable people to utilize the hidden knowledge possessed within the experts. • Provide both technical and financial values from the utilization of hidden knowledge
Solution	• Implement Knowledge Management System to disseminate and fully utilize the hidden knowledge within the organizational context

Firstly, the context level of power transformer hidden knowledge is shown by constructing CommonKADS Organization Model. It is represented in table IV to VI. The table IV provides the necessities of hidden knowledge implementation for the organizational context using worksheet OM-1 template. Using worksheet OM-2 template, involvement of employees, existing resource and required knowledge for power transformer life cycle management are identified and presented in table V.

TABLE V
DESCRIPTION OF ORGANIZATIONAL ASPECTS AFFECTING BY KMS

Organization Model	Variant Aspects Worksheet OM-2
People	• Senior Planning Engineers • Operation & Maintenance Engineers • Technicians
Resource	Power Transformer Data Inventory System
Knowledge	• Planning Knowledge • Engineering Knowledge • Transportation Knowledge • Installation Knowledge • Commissioning Knowledge • Operational and Maintenance Setup • Corrective Maintenance Learning • Preventive Maintenance Learning • Visual Inspection Learning • Training Knowledge

TABLE VI
DESCRIPTION OF TASKS AND KNOWLEDGE COMPONENT

Organization Model			Process Breakdown and Knowledge Assets Worksheets OM-3 & OM-4		
Task	Performed By	Where	Knowledge Asset	Significance	Used In
Bidding Preparation	Senior Planning Engineer	Acquisition Stage	Planning Knowledge	0.25% of Asset Price	Relocation of PT & Procuring
Detail Design Drawings	Engineers of Manufacturer	Acquisition Stage	Engineering Knowledge	3.0% of Asset Price	Relocation of PT; Procuring and at the end of FDL
Dispatch & Receiving	Supervisor of Contractor	Acquisition Stage	Transportation Knowledge	10.0% of Asset Price	Relocation of PT & Procuring
Installation & Energizing	Supervisor of Contractor	Acquisition Stage	Installation & Commissioning	5% & 3% of Asset Price	Relocation of PT & Procuring
Operation & Maintenance	O&M Expert	O&M Stage	CML; PML; VIL and O&M SetUp	O&M Expert One-Man day/year for learning and 10 Man-Day for Set Up	Operating the PT
Training of Employee	Trainer of Contractor	O&M Stage	Training Knowledge	About 2% of Asset Price	O&M Stage in every 5 year

The different tasks or activities involved in each phase of life cycle of power transformer are categorized on the followings aspects using the worksheet OM-3 and OM-4 template shown in table VI.

- Who perform the tasks?
- Where is the task performed?
- What is the knowledge required to perform the tasks?

- What is the contribution of each task in terms of financial?
- Where is this required knowledge used in?

Secondly, the concept level diagrams are shown in fig. 2 to fig.6. CommonKADS Knowledge model is represented in fig. 2 to fig. 4 providing the relationships among task knowledge, inference knowledge and domain knowledge. Similarly, the fig. 5 shows the ratio test of power transformer. Thirdly, the fig. 6 presents the artifact level diagram of ratio test.

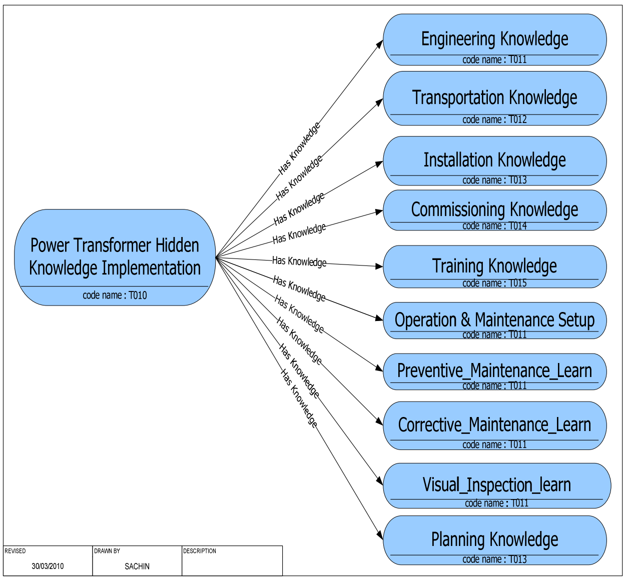

Fig. 2 Task Knowledge Diagram

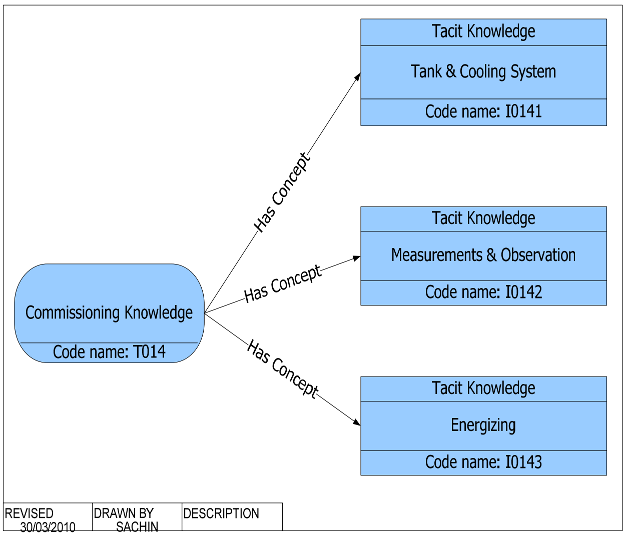

Fig. 3 Inference Knowledge Diagram

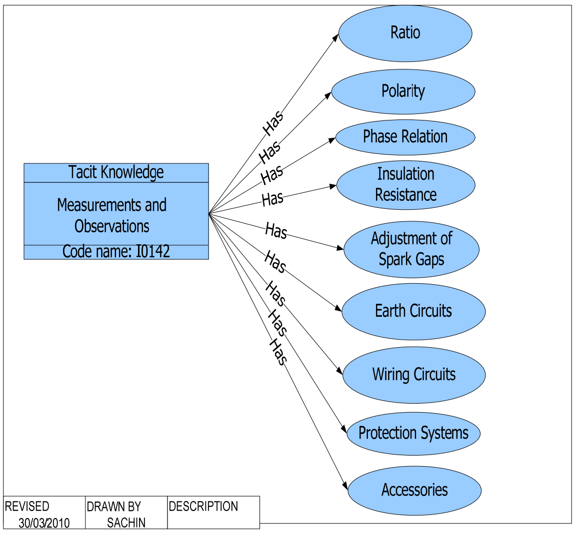

Fig. 3 Domain Knowledge Diagram

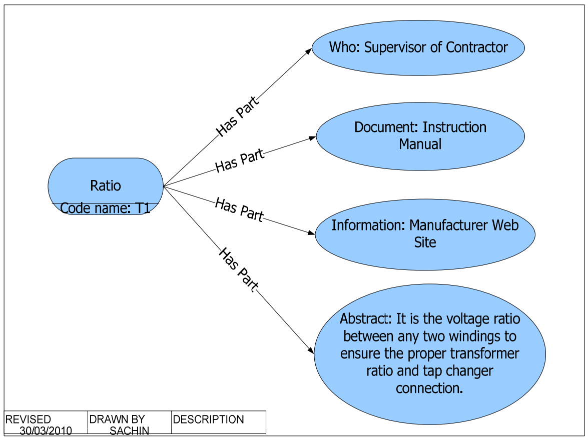

Fig. 5 Key Ontology Diagram

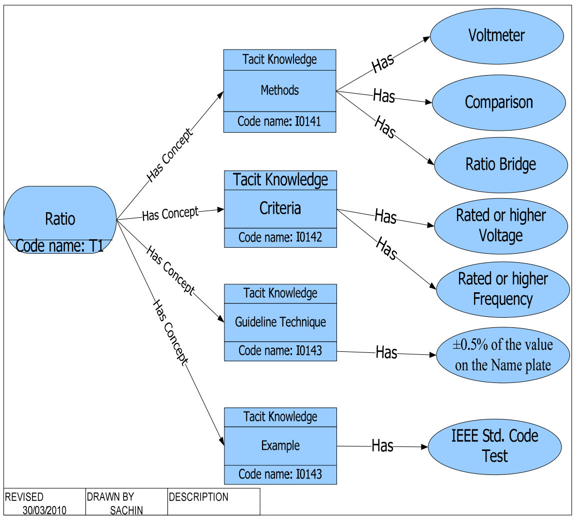

Fig. 6 Support Tacit Knowledge Diagram

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To make utilize of the knowledge framework by constructing the knowledge management system, the captured knowledge models are implemented using Microsoft Share Point [16]. It is selected because it enables people to make better-informed decisions and also connects people information and expertise. The example of hidden knowledge implementation using Microsoft Share Point is shown in fig. 7. The embedded knowledge is updated and maintained in every five years through hiring an expert for one day.

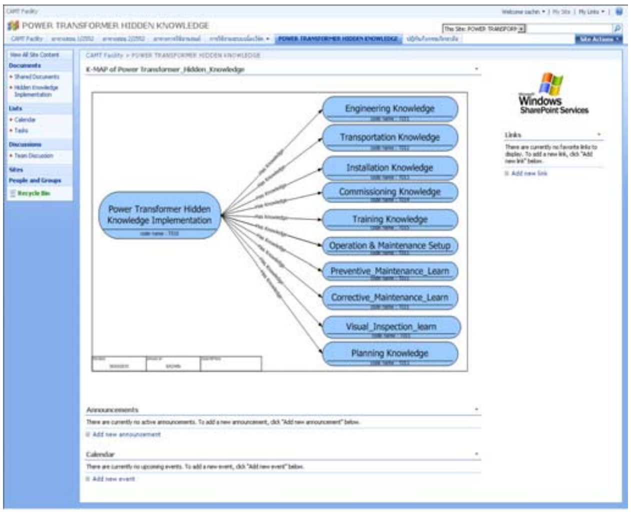

Fig. 7 Implementation in Microsoft Share Point

The results are verified with the help of expertise of Nepal Electricity Authority and Nepal EKARAT Engineering Co. Pvt. Ltd. The knowledge becomes well structured and more manageable.

The results show that the CommonKADS methodology provides a structure to identify, capture, model and utilize the knowledge involved during the life cycle of power transformer systematically. Eventually, utility can effectively assess the life cycle of power transformer during load violation with their proper utilization.

VI. Conclusion

The aim of the knowledge based model is to support utility companies for managing the knowledge they currently possess, and to focus their operations towards knowledge reuse. Knowledge engineering is one approach in the development of knowledge based model. By using the CommonKADS Model Suite, hidden knowledge embedded within power transformer is characterized, modeled, and utilized within the power utility and consequently implemented for sharing and dissemination.

This paper shows that the hidden knowledge of power transformer can be categorized into two stages and each hidden knowledge is explained into three different levels using Knowledge Engineering and Management methodologies. Hence, utility can fully utilize the hidden knowledge, achieving both financial and technical values, to be used during the life cycle decision on power transformer in order to maximize the utilization of power transformer on the network.

Appendix

EC	Engineering Cost
TC	Transportation Cost
PT	Power Transformer
TC	Transportation Cost
IC	Installation Cost
CC	Commissioning Cost
OC	Operational and Maintenance Cost
TrC	Training Cost
VIL	Visual Inspection Learning
CML	Corrective Maintenance Learning
PML	Preventive Maintenance Learning
PC	Planning Cost
OMSC	Operational Maintenance Set Up Cost

References

[1] R.E. Brown, B.G. Humphrey, "Asset Management for Transmission and Distribution", IEEE Power & Energy Magazine, vol. 3, no. 3, pp. 39-45, May-June 2005.

[2] British Standards Institution, PAS 55: Asset Management. Part 1: Specification for the Optimized Management of Physical Infrastructure Asset, 2004.

[3] L.C. Leung, S. K. Khator, "Transformer Procurement and Relocation at a Large Electric Utility: A Mixed 0-1 Linear Programming Model", IEEE Trans on Power Systems, Vol. 10, No. 2, May 1995.

[4] J. Ostergaard, A.N. Jensen, "Can We Delay the Replacement of this Component? - An Asset Management Approach to the Question", 16th International Conference and Exhibition on Electricity Distribution (CIRED2001), Amsterdam, 18-21 June, 2001.

[5] H. Picard, J. Verstraten, M. Hakkens, R. Vervaet, "Decision Model for End of Life Management of Switchgears", 4th European Conference on Electrical and Instrumentation Applications in the Petroleum and Chemical Industry, Paris, France, 13-15 June, 2007.

[6] G. Schreiber, H. Akkermans, A. Anjewierden, R.de Hoog, N. Shadbolt, W. van de Velde, B. Wielinga, "Knowledge Engineering and Management: The CommonKADS Methodology", The MIT Press, 2000.

[7] N. Shadbolt, N. Milton, "From Knowledge Engineering to Knowledge Management", British Journal of Management, vol. 10, pp. 309-322, 1999.

[8] J. Angele and D. Fensel and D. Landes and R. Studer, Developing Knowledge based systems with MIKE, Journal of Automated Software Engineering, 1998.

[9] MOKA Home Page, Available at URL: http://web1-eng.coventry.ac.uk/moka/: Last Accessed April 2010.

[10] G.Booch, J.E. Rumbaugh and I.Jacobson, The Unified Modelling Language User Guide, Addison-Wesley, Reading, MA, 1999.

[11] M.S. Abdullah, A. Evans, I. Benest, R. Paige, C. Kimble, " Modelling Knowledge Based Systems Using the eXecutable Modelling Framework (XMF) ", IEEE, Conference on Cybernetics and Intelligent Systems, Singapore, 2004.

[12] M.S. Abdullah, I. Benest, A. Evans, C. Kimble, " Knowledge Modelling Techniques for Developing Knowledge Management Systems ", 3rd European Conference on Knowledge Management, Ireland, September, 2002.

[13] G. Balzer , W. Degen , K. Laskowski , M. Halfmann, T. Hartkopf , C. Neumann, "Strategies for Optimizing the Use of Substation Assets", On behalf of CIGRE Work Group B3-1: Substations, (CIGRE Paris 2004).

[14] S.S. Bhandari, T. Chandarasupsang, "Alternative Life Cycle Assessment of Power Transformer", 3rd International Conference on SKIMA-09, Fes, Morocco, 21-23 October, 2009.

[15] K. Khankasikam, " Knowledge Capture for Thai Word Segmentation by Using CoommonKADS", 2nd International Conference on Computer and Automation Engineering, Singapore, January 2010.

[16] Microsoft Office Share Point Server, Available at URL: http://office.microsoft.com/en-us/sharepointserver/: Last Accessed April 2010.