TNB APPROACH ON MANAGING ASSET RETIREMENT FOR DISTRIBUTION TRANSFORMERS

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ABSTRACT

TNB has a population of nearly 74,000 distribution transformers with rated capacity from 100 kVA to 1000 kVA installed in its network. Managing life cycle activities of distribution transformers, in particular to implement maintenance and retirement programs, poses a great challenge due to its very large population. In addition, problem of high premature failure rate of distribution transformers has added to the complexity of managing the retirement of the transformers. Most of these transformers have been scrapped based merely on the results of test conducted without any economical consideration. This has contributed to high number of write-off which gave rise to company's cost per unit kWh generated. Furthermore, failure modes and causes of failed distribution transformers are often unknown as failure investigation was not carried out. This paper presents TNB approach on managing asset retirement of distribution transformers with the use of Asset Retirement Management System (ARMS) developed as part of the initiatives under TNB Asset Management Framework.

INTRODUCTION

Tenaga Nasional Berhad (TNB), an electric utility company in Malaysia has developed an Asset Management (AM) System to ensure effective asset management and to improve performance as well as reliability of its distribution network. In building up the overall framework to support its AM system, TNB has adopted the principles within BSi PAS 55:2008 and sets the foundation for AM policy, strategy and plan to be in line with its organization objective [1]. One of the key elements of the framework is the implementation of asset life cycle management which covers the complete asset life cycle activities from acquisition, operation, maintenance and retirement of the network assets [2]. As a start, focus on life cycle management has been given to critical assets namely medium voltage primary equipment such as power and distribution transformers.

TNB has a population of about 1,340 medium voltage power transformers rated at 33/11kV, 22/11kV and 22/6.6kV in its distribution network. On the other hand, there are nearly 74,000 distribution transformers rated at 33/0.433kV, 22/0.433, 11/0.433kV and 6.6/0.433kV installed in the network. Though priority are given to medium voltage power transformers in implementing life cycle management approach, the real challenge lies in managing the distribution transformers, in particular to implement maintenance and retirement activities due to its very large population and high mortality rate. A reliability analysis conducted based on a statistical method called Life Data Analysis using Weibull-Bayesian distribution method shows premature failure of TNB distribution transformers installed between 2006-2012 is high with the predicted mean life of only about 20 years for the entire batch installed between the period [3] as compared to the industry view of 43 years mean life [4].

Furthermore, failure modes and causes of failed distribution transformers are often unknown as failure investigation was not carried out and little is known about the condition prior to the failure. All failed distribution transformers will be immediately replaced with new units for fast supply restoration and are not repaired on site. The failed units will be credited back to the warehouses in which inspection and tests will be conducted. A decision for repair or scrap will then be made by an approving committee based merely on the results of these inspection and tests. Apart from failed units, the same warehouses or stores will also manage and receive other distribution transformers dismantled from the network.

Clearly, with limited historical failure data, unknown modes and causes of failures, lack of analytical tool to aid decision making for repair or scrap, are among factors that hindered continual improvement program to reduce number of failures of distribution transformers and number of write-off. As the consequences, in fiscal year 2012-13 for example, the total number of write-off amounted to 1615 units of distribution transformers with the average life of 22 years and valued at RM 13.2mil (approx. US$ 3.9mil). On the other hand, the percentage of repaired transformers over total number of retired distribution transformers was only in between 5% to 10%. Thus, it is timely that a more systematic approach for managing retired transformers should be established.

This paper presents TNB experience and challenges through the use of Asset Retirement Management System (ARMS) developed to improve the effectiveness in managing retirement of distribution transformers as part of the initiatives to enhance performance and reliability of distribution network as outlined by TNB AM strategy and plan.

BACKGROUND

Distribution transformer population in TNB is approaching 74,000 units with rated capacity from 100 kVA to 1000 kVA installed in its distribution network. Distribution transformers with capacity of 300 kVA and below are normally installed as pole mounted whilst larger capacity transformers are installed as ground mounted in an indoor or outdoor substation. All distribution transformers are of oil immersed type with majority are of hermetically sealed design. Since 1990 free breathing conservator design was no longer used for new installation. The age profile of distribution transformers are as shown in fig. 1.

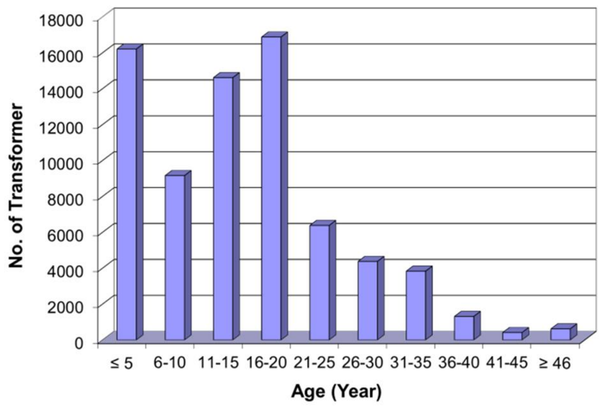

Fig. 1: Age profile of distribution transformers

Maintenance strategy applied to distribution transformers are Time Based Maintenance (TBM) and Condition Based Maintenance (CBM). The interval of which TBM or CBM is conducted on a transformer depends on the area classification, value of load loss and criticality of the transformer based on risk assessment and life cycle cost analysis of transformer fleet. In addition, condition health index is also applied in CBM to determine maintenance priority or end of life of the transformer. The main objective of TBM and CBM is to prolong the life span of the distribution transformer until retirement is unavoidable.

ASSET RETIREMENT OBJECTIVE AND CRITERIA

The objective of asset retirement is to provide alternative solutions to the dismantled asset either to be refurbished for reuse, relocation or disposed/scrapped. Retirement of distribution transformer can only be executed when the following retirement criteria are met:

- Failure of distribution transformer to operate due to electrical or mechanical faults such as flashover, damage by third party or act of vandalism and verified through tests and inspection.
- End of life of the transformer is reached when the transformer has reached 40 years of operating life with deterioration of its condition health index Ò5 as stated in TNB Distribution Asset Replacement Policy and Guidelines. The diagnostic techniques to determine the health index are as described in TNB Transformer Maintenance Manual. The End of Life is also applied to transformer with high total life cycle cost due to the need for frequent maintenance and repair.
- Capacity of the distribution transformer has reached 100% and can no longer satisfy continuous load demand. On the other hand, one of the transformers used in a double chamber substation can also be retired when total capacity of both units is idle at less than 50% with no prospect for future load increase.

DEVELOPMENT OF ASSET RETIREMENT MANAGEMENT SYSTEM (ARMS)

ARMS is a web based application developed currently for distribution transformers incorporating the asset retirement criteria above. The development of its modules was primarily based on the feedback and user requirements obtained throughout the software development stage. It is an extension to the existing TNB Distribution Maintenance Management System (DMMS) aiming to provide easy access to historical maintenance data and test results.

Objectives

ARMS is developed to meet the following objectives:

- To be the source of information for reliability analysis and improvement of design and manufacturing process to reduce number of distribution transformer failures.
- To reduce the number of write-off for distribution transformers and contribute to reduce Cost per Unit kWh generated.
- To provide systematic approach in managing retirement of distribution transformers in accordance with financial policy and procedures.
- To provide a tool based on life cycle cost analysis (LCCA) to aid decision making on repair or scrap of retired distribution transformers.
- To prepare for future long term planning of the retirement and replacement of high ranking distribution transformer before failure occurs.

Functionality

ARMS consists of six key modules; namely, the Network Operator (Kawasan), Warehouse, Service Providers/OEM, Quality Assurance, Engineering Services and Approving Committee (known as Board of Survey ï BOS) Reporting Modules. ARMS will be used to record, track and manage the retirement processes. Fig. 2 illustrates the overall functionality of ARMS software.

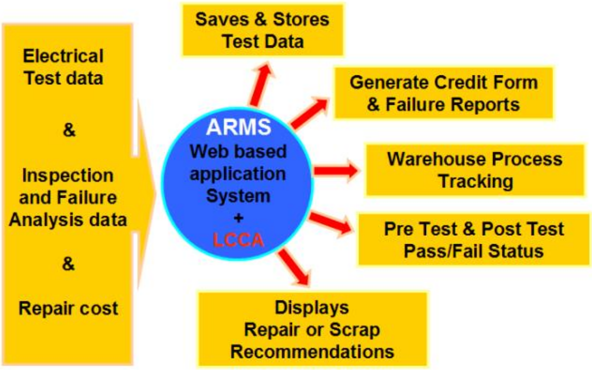

Fig. 2: ARMS overall functionality

Retirement Categories and Processes

The retirement categories or also known in financial terms as credit categories in the software, are derived from the asset retirement criteria to suit each process requirement. The categories are intended to capture the reason why the transformer is retired and credited back to the warehouse. It is also intended to ease data tracking.

Table 1: Retirement categories for distribution transformers

No	Retirement Category	Description
1	*ITC/DTC – Reusable*	Retirement of distribution transformers aged less than 40 years in service for Improve Transformer Capacity (ITC) or Derate Transformer Capacity (DTC)
2	*Failure – Under Warranty*	Failure of in-service distribution transformer to operate due to electrical or mechanical faults. Transformer is under *warranty* aged 2 years and below
3	*Failure - Expired Warranty (below 16 years)*	Failure of in-service distribution transformer to operate due to electrical or mechanical faults. Transformer aged more than 2 years but less than 16 years
4	*Failure - Expired Warranty (above 16 years)*	Failure of in-service distribution transformer to operate due to electrical or mechanical faults. Transformer aged more than 16 years
5	*Decom/Dismantle – Unusable*	Retirement of distribution transformers aged 40 years in service and above and meeting End of Life criteria

Pre-simulation on the variety of retired units of different capacity, age and condition using the LCCA model showed that distribution transformers aged from 16 years old and above were not feasible for reuse even with minor repair cost. Hence, 16 years has been chosen as the cut off age for decision making for failed distribution transformers. The retirement processes applied in ARMS for the above categories are shown in fig. 3, except for Category 2 which is shown in fig. 4. The main difference between the new ARMS processes as compared to the previous ones is the implementation of postmortem or post-test together with failure analysis on failed distribution transformers and the use of LCCA for refurbish or scrap decision making.

The processes involve interdepartmental as well as external collaboration. Therefore, in order to ensure smooth and effective implementation of the processes at controlled service price, the service provider or OEM appointed for testing, inspection and repair of the transformers is managed through contractual agreement. At the same time, tagging system is also developed at the warehouses for better management of the retired assets. Proper protection of failed transformers to prevent further destruction from rain and other environmental factors is also being considered.

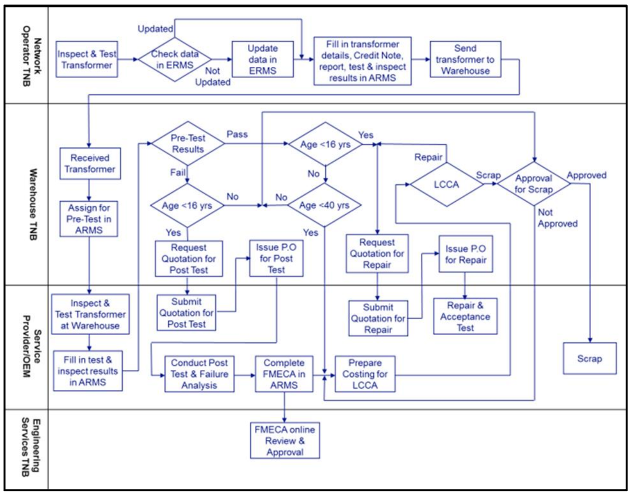

Fig. 3: ARMS process flow for Category 1, 3, 4 and 5

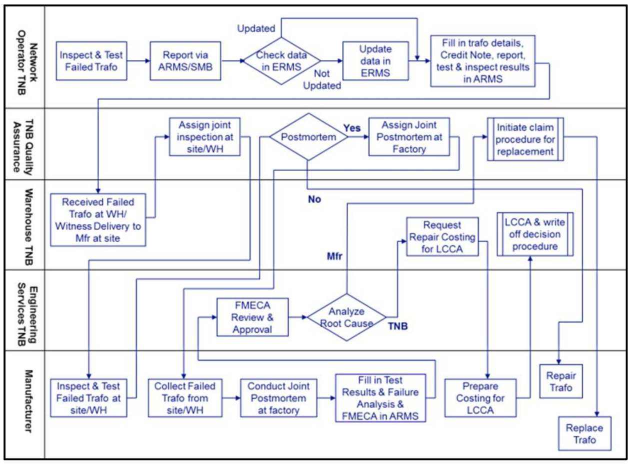

Fig. 4: ARMS process flow for Category 2

Postmortem and Failure Analysis

Under the new ARMS process, postmortem or post-test, and failure investigation and analysis are mandatory for all failed distribution transformers [5]. The main objective is to find failure mode and root cause of failure [6]. Untanking for internal inspection and electrical tests are conducted to aid the process of identifying the failure mode and the root cause. The online failure report by the network operator is also referred.

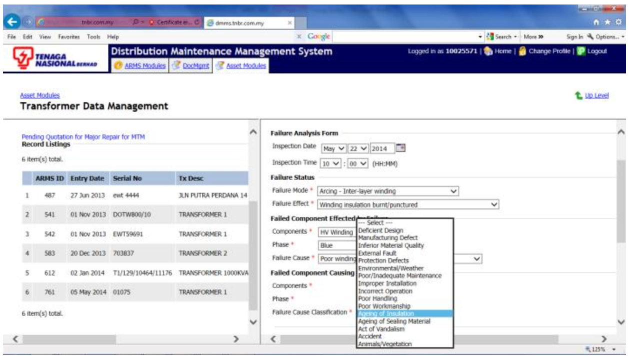

Fig. 5: Determining failure mode and root cause using ARMS

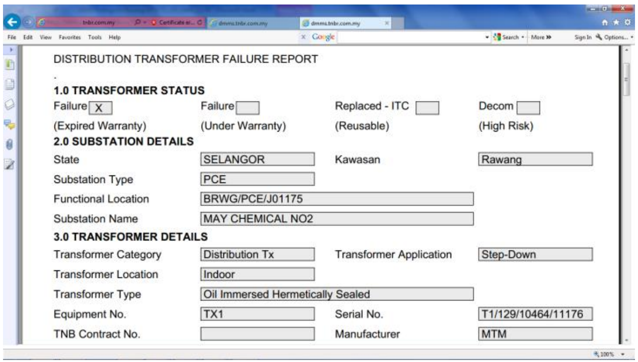

Fig. 6: Online transformer failure report by network operator

Life Cycle Cost Analysis (LCCA)

The capability to make the correct decision is essential to meet the goals of maximizing return on investment. Hence, LCCA is used to aid decision making in ARMS on whether a retired transformer is more economical to refurbish or scrap [7]. Fig. 7 shows the LCCA integrated template used in ARMS.

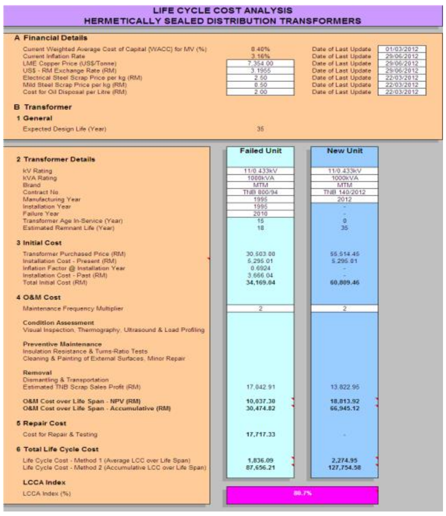

Fig. 7: LCCA integrated template used in ARMS

The LCCA model adopted is shown in equation (1).

$$\mathbf{LCC_{TX} = C_I + C_O \pm C_D} \qquad (1)$$

Where,
LCC_{TX} = Life Cycle Cost of Transformer
C_I = Initial Cost
C_O = Operation and Maintenance Cost
C_D = Disposal Cost

The net present value of transformer total life cycle cost is normalised with respective of the usage year as shown by equation (2).

$$LCC_{Average} = \frac{LCC_{TX}}{n} \qquad (2)$$

The ratio known as LCC Index was established and taken as percentage as indicated by equation (3).

$$LCC\ Index\ (\%) = \frac{LCC_{Average}\ Dismantled\ Unit}{LCC_{Average}\ New\ Unit} \times 100\% \qquad (3)$$

The use of LCC Index is further illustrated by Fig 8. The retired distribution transformer rated at 1000 kVA installed in 1995 was dismantled in 2012 due to failure. The total life cycle cost of the dismantled unit inclusive of refurbishment cost is computed and compared against the total life cycle cost of a new transformer with the same rating. Ratio of the average life cycle cost of the dismantled unit to the average life cycle cost of the new unit is called the LCC Index. If LCC Index produced is 100% or above, then the new unit will replace the dismantled unit and the dismantled unit will be scrapped. However, if LCC Index is below 100%, then the dismantled unit will be refurbished.

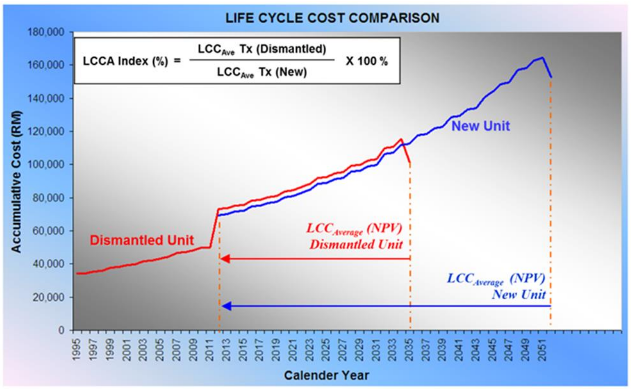

Fig. 8: Life cycle comparison to determine LCC Index

The assumptions below are used to calculate the LCCA:

- The operating life of a transformer is 40 years.
- Occurrence of failure only affects the transformer and no other installations. Hence, only the cost of transformer is taken into account.
- Either the repaired or new unit is to be installed at the same substation.
- Transformer is oil filled hermetically sealed ground mounted, applying the same maintenance strategy.
- All dismantling or reinstallation works carried out

through external contract services with supervision by a TNB personnel
- All future costs are subjected to incremental change with inflation rate.
- Distance of substation is within 40 km.

THE IMPLEMENTATION OF ARMS

ARMS has been rolled out for use in TNB since 2013 in the metropolitan area involving the states of Selangor, Kuala Lumpur and Putrajaya. By the end of 2014, a total number of 508 units of retired distribution transformers have been managed through ARMS. Since its application, the rate of refurbishment of failed distribution transformers has gone up from around 5% - 10% previously to more than 60%. This has contributed to the reduction of the total number of write-off units nationwide for fiscal year 2013-14 to 1134 distribution transformers valued at RM 8.3mil (US$ 2.4 mil) as compared to 1615 units valued at 13.2mil (approx. US$ 3.9mil) in the previous fiscal year 2012-13.

Based on postmortem conducted on 160 units of failed distribution transformers, arcing in windings (71 cases) is the most common failure mode found. The undetermined failure mode is due to the severe condition of the windings which have been heavily soaked in water due to over exposure to rain and environment. These units are normally failed transformers that experienced bushingsô damage or tank leaks.

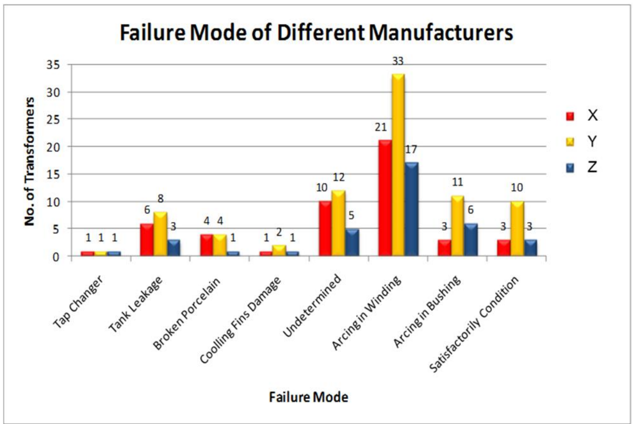

Fig. 9: Failure modes of failed distribution transformers

The application of LCCA and ARMS in general to aid decision making and management of retired transformer has proven very useful and effective to the Approving Committee and resulted in the increased number of refurbished transformers and reduction in number of write-off as previously mentioned.

Challenges in implementing ARMS include:
- Require handling of massive historical and operational data for LCCA calculation. Furthermore, data, in particular financial data, need to be consistently updated to ensure accurate analysis.
- Unavailability of data for transformer installed before 1995 has forced a lot of estimation that may result in inaccuracy of LCCA calculation.
- Tracking physical assets involve frequent administrative review meetings to ensure speedy movement of assets.
- Time taken for conducting postmortem and investigation, limited space at service providerôs facility and logistic problem had slowed down the speed of the process causing space constraint and increase of blocked stock at warehouses.
- Increased number of refurbished transformers at warehouses also causing space contraints as netwok operators prefer new transformer to refurbished ones.

CONCLUSION

Managing asset life cycle activities is the main focus of asset management system starting from the creation of the asset, utilization, maintenance up to its retirement. Thus, each aspect of the life cycle activities must be strategized to optimize the usage of the asset and to strike a balance between cost, risk and performance of the asset. Consequently, management of the asset retirement should also be taken seriously so that the cause for the retirement can be studied to formulate enhancement of the asset for continual improvement program. In that respect, ARMS has become an effective management tool that able to record, track, analyse failure and aid the decision making of retired distribution transformers in TNB. With a few enhancements into its maturity, ARMS will be rolled out to the entire Distribution Division TNB in the near future and may be used to prepare for future long term planning of the retirement and replacement of distribution as well as power transformers.

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