MANAGING AGEING BARE OVERHEAD LINE ASSETS IN TNB DISTRIBUTION NETWORK

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ABSTRACT

Currently, TNB operates and maintains 702 kM of 11kV, 184 kM of 22kV and 5,285 kM of 33kV bare overhead lines. About 700 kM of 11kV and 22kV bare overhead lines have already been in service for more than 50 years while about 3,000 kM of 33kV bare overhead lines have been commissioned for more than 30 years. Due to this ageing factor, the performance of these bare overhead lines tends to deteriorate causing an increase in cost and safety risk to operate these assets. To refurbish and replace these ageing assets requires high capital cost and long duration. Thus, to improve and extend the remaining service life of these ageing bare overhead lines, optimized operations and maintenance regime needs to be put in place. Hence, as part of the above initiative, TNB has developed an asset management strategy that includes the following activities among others:

1. *Engineering practices assessment to help identify and rectify any installation abnormalities due to ageing;*
2. *Standardized maintenance and CBM regime that includes the use of aerial CBM inspection and scanning to help monitor the conditions and health of these ageing bare overhead lines;*
3. *Strategic spares management to improve the overall system performance by replacing critical components exposed to ageing agents*

Hence, this paper will attempt to illustrate that with the above strategies and solutions, certain degrees of improvement have been attained by reducing failure rates and minimizing exposures to controllable threats that affects the reliability of these ageing bare overhead lines.

INTRODUCTION

The Asset Management Manual and Policy for Distribution Division, TNB has been developed to illustrate how asset management can contribute towards TNB Business Plan objectives to achieve the following:

a. Customer Satisfaction Index (CSI) of 7.5
b. SAIDI of 50 minutes/customer/year
c. Losses Reduction to 5%

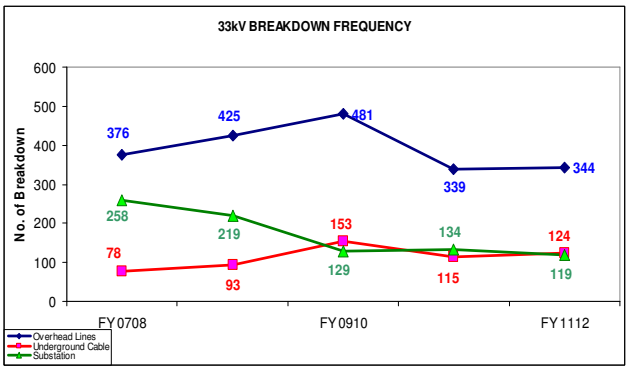
Thus, in order to achieve the above, structured asset management strategies and initiatives need to be put in place to ensure that all assets within the organization function and operate as they are intended to throughout their life cycle.

Unfortunately, an asset will be subjected to wear and tear; hence, at one point of its life cycle, the asset physical condition will deteriorate and so is the asset performance. Fortunately, with timely intervention, physical age of an asset can be extended to allow the asset to provide the needed output during its remaining service life.

Criticality of MV Bare Overhead Lines

In TNB distribution network, the medium voltage bare overhead line system is being used to deliver electricity supply to remote load centres. However, due to its natural design, bare overhead lines are exposed to risks that can lead to breakdowns such as lightning, weather, vegetation, animal and encroachment. As such, TNB has migrated to the use of medium voltage aerial bundled cable (ABC) as alternative and the MV ABC system has expanded from a mere 2,500 kM in 2004 to 24,000 kM in 2014.

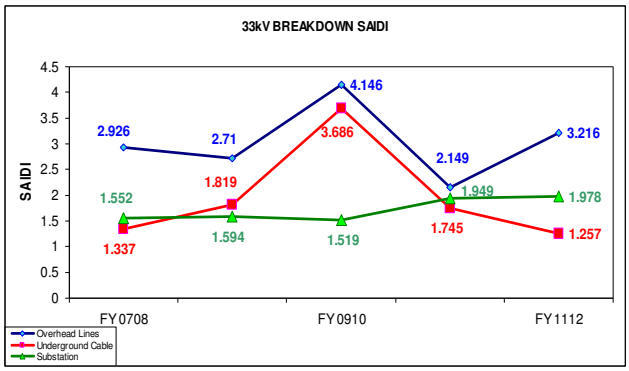
As the medium voltage bare overhead lines age, their performance in terms of number of breakdown and SAIDI seems to be deteriorating. As illustrated in Graph 1 below, the 33kV bare overhead lines are experiencing more breakdowns than underground cable and substation systems.



Graph 1: 33kV Network Breakdown Frequency

The other issue with medium voltage bare overhead lines is proximity. Most medium voltage bare overhead lines cut through jungle, plantations and swampy in the rural areas. As such, with limited accessibility, proximity tends to dampen restoration process. With the high number of breakdowns, it is natural that SAIDI increases as indicated in Graph 2 overleaf. Thus, in order to reduce SAIDI on the ageing medium voltage bare overhead line,

failures need to be contained with cost effective asset management activities.

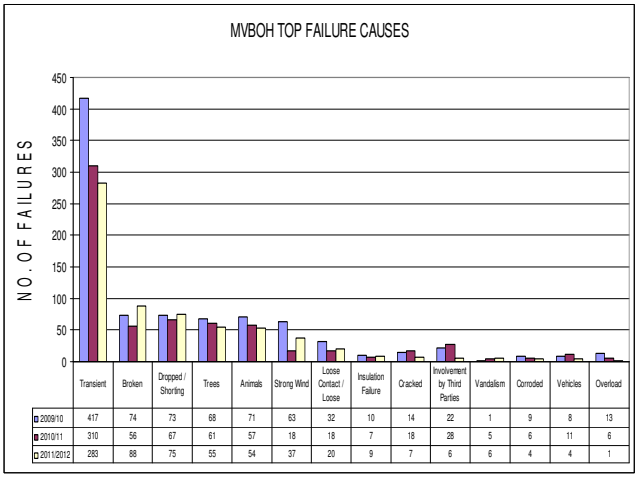


Graph 2: 33kV Network SAIDI

Common Failures and Risks

Based on FMECA, transient interruptions are still the main cause for medium voltage bare overhead lines as shown in Graph 3 below. Although transient trippings can be attributed to many risk factors, ageing can also be a major risk factor to the reduced performance of the medium bare overhead lines as ageing can contribute to the following:

a. Corrosion
b. Loose contact
c. Reduced critical flashover voltage or dielectric
d. Contamination



	Transient	Broken	Dropped / Shorting	Trees	Animals	Strong Wind	Loose Contact / Loose	Insulation Failure	Cracked	Involvement by Third Parties	Vandalism	Corroded	Vehicles	Overload
2009/10	417	74	73	68	71	63	32	10	14	22	1	9	8	13
2010/11	310	56	67	61	57	18	18	7	18	28	5	6	11	6
2011/2012	283	88	75	55	54	37	20	9	7	6	6	4	4	1

Graph 3: Top Failure Causes for MV Bare Overhead Line

Asset Management Strategies for MV Bare Overhead Lines

As per Asset Management Manual & Policy for Distribution Division, TNB, once commissioned, the operation strategy adopted for MV bare overhead lines is "find & fix" where standardized inspection procedures by utilizing infra-red thermography, airborne ultrasound detection and line patrolling to manage risks and to monitor the condition or health of the asset.

As the MV bare overhead line asset performance or condition deteriorates, the standing policy is to carry out upgrading projects or to replace it with aerial bundled cable system or ABC with the latter being the preferred alternative as it is easier to manage and faster to complete.

Age Classifications for MV Bare Overhead Lines

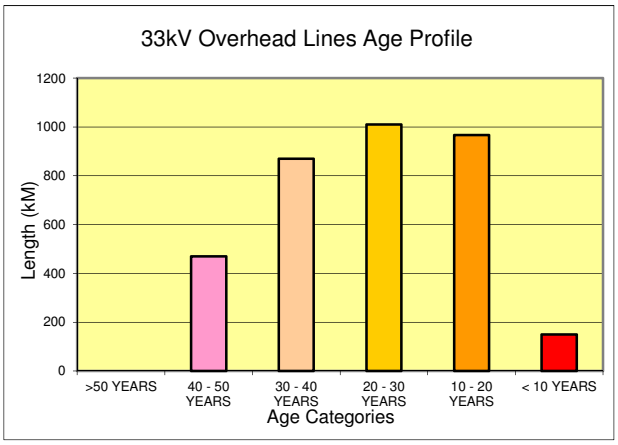
An asset has both the economic life and operating or physical life to be considered throughout its life cycle that includes:

a. Procurement stage
b. Operations stage
c. Disposal preparation stage

An economic life of an asset determines the expected useful life and is used to calculate the depreciation of an asset. It is usually related to technological progress where it may no longer able to compete with newer technologies or it is no longer relevant to the asset owner business needs.

The operating or physical life is affected by the wear and tear of the asset and is related to chronological age. However, with enhanced maintenance, rehabilitation and physical improvement, the operating or physical life can be considerably prolonged or extended.

Currently, overhead lines operating at 33kV and below in TNB distribution network has an average economic life of 20 years and an average operating or physical life of 40 years.



Graph 4: 33kV Bare Overhead Line Age Profile

Thus, from the age classification abovementioned, about 65% of the 33kV bare overhead lines are above the economic life while about 26% of them are beyond the operating life.

To further classify the ageing bare overhead lines, the number of failures per feeder is also taken into consideration. Thus, any overhead line feeders that are experiencing three failures per month are categorized in the Worst Performing Feeders. With this additional categorization, an overhead line commissioned more than 40 years and is experiencing more than 3 failures a month is considered critically ageing.

ENGINEERING PRACTICES ASSESSMENT

Engineering Practices Assessment is focused on visual inspection to detect installation abnormalities due to ageing. Components that are usually given special attention due to exposure to accelerated ageing are as follows:

a. Corroded/snapped conductor
b. Corroded/deformed pole or tower
c. Broken/contaminated insulators
d. Broken/brittle wooden crossarms
e. Corroded/snapped earthwire
f. Loose/corroded/contaminated connectors

CONDITION BASED MAINTENANCE (CBM) FOR MV OVERHEAD LINES

CBM is a methodology to decide on maintenance activities based on test results that monitor the condition of the MV bare overhead lines. As maintenance or repair works on faulty components can be carried out before any failure occurs, breakdowns can be reduced. Moreover, CBM can be carried out on-line or without scheduling any shutdown; thus, equipment, financial and human resources can be optimized.

The standardized CBM deployed in Distribution Division, TNB to monitor ageing MV bare overhead lines utilizes the followings:

a. Infra-Red Thermography
b. Ultrasound Detection

Infra-Red Thermography

Thermal imaging, or better known as infrared thermography (IRT), is commonly used for CBM for bare overhead line. When current-carrying equipment is at fault, it operates beyond its normal operating temperature. This temperature rise can be detected based on the thermal radiation concept. Nevertheless, extra care must be taken in order to ensure that the localised heat detected is primarily due to the fault, not from thermal reflection by other external sources.

Using IRT camera, the thermal variances of the electrical components of MV bare overhead lines can be determined. The information can then be used to assess the condition of the system and thus, actions to be taken by TNB personnel can be strategized accordingly. This will in turn optimize maintenance and keep the network system running continuously and safely at the lowest possible cost.

TNB adopts the classification of severity index of electrical apparatus condition based on ΔT proposed by the InterNational Electrical Testing Association (NETA) and can be referred to Table 1:

ΔT (°C)		Severity	Description
with respect to same component	with respect to ambient temperature		
1 – 3	1 – 10	Low	Possible deficiency; warrants investigation
4 – 15	11 – 20	Minor	Indicates probable deficiency; repair as time permits
	21 – 40	Serious	Monitor until corrective measures can be accomplished
> 15	> 40	Critical	Major discrepancy; repair immediately

Table 1: NETA Severity Index for IRT

Ultrasound Detection

Ultrasound detection (USD) method is where the ultrasonic signal emitted by a faulty component is detected. When energized electrical equipment experiences some form of defects, the surrounding air near the faulty region ionizes; producing high frequency sound typically in the radio frequency (RF) range. With a highly sensitive detection system, this ultrasonic signal can be obtained and the type of discharge can be analysed. However, this technique can lead to misinterpretation of results as it can also collect signals not related to the fault.

Ultrasound detection (USD) is one of the most established methods to assess the condition of high voltage equipment. This technique employs the detection of sound effects due to ionization of gas molecules within the air vicinity. The sound that is being generated by this process has a frequency above the human hearing ability. The range of the human audible frequency is between 20 Hz to 20 kHz. USD enables the detection of sound wave beyond 20 kHz.

At the moment, there is no standard approach in

determining the severity index of electrical apparatus based on its ultrasonic dB levels. The standard procedure adopted by TNB Transmission (TNBT) is to take action when a USD signal of above 1 dB has been detected. In terms of the severity, arcing discharges can be considered as the most severe, followed by tracking and lastly corona. Thus maintenance action can be prioritized based on the Table 2 below:

dB level	Type of PD Activity		
	Corona	Tracking	Arcing
> 1	Low	Moderate	High
Description	Defect developing; monitor in 6 months	Defect progressing; repair in 3 months	Defect worsening; repair immediately

Table 2: TNB Severity Index for USD

Aerial Scanning and Inspection

In order to allow faster CBM scanning and inspection, TNB is deploying aerial CBM scanning and inspection using helicopters. The main advantage of employing such methodology includes the followings:

a. Reduced inspection duration of the overhead line over long distances
b. Faster results can be acquired to allow early detection of impending defects
c. Real-time assessment of the overhead line and its right-of-way corridor
d. Incipient fault can be detected at an early stage
e. Inspection of inaccessible or difficult and rough terrains
f. Reduced personnel cost for overhead line patrolling and inspection

STRATEGIC SPARES MANAGEMENT

From the FMECA and physical inspection done, major components exposed to frequent accelerated ageing or failure are identified. Further analysis to improve on the quality and reliability of the components has been done. With the analysis, technical specifications are revised and improved to ensure extended life.

LESSONS LEARNED

In order to manage ageing medium voltage bare overhead lines, condition based maintenance is a preferred methodology as it is cost efficient and it allows optimized deployment of resources. Although rehabilitation and replacement is the ultimate goal, the cost and duration to realize such strategy can be challenging. Modernization of ageing asset can also help to improve certain degree of performance but that too can incur cost and time.

RESULTS

With the above strategies and solutions, these ageing bare overhead lines have shown certain degrees of improvement by reducing the failure rate and minimizing exposure to risks as shown in Table 1 below:

kV	FY 08/09	FY 09/10	FY 10/11	FY 11/12	FY 12/13	FY 13/14
33	7.51	9.19	4.67	5.22	4.30	4.28
22	21.01	21.40	46.20	52.72	22.44	15.09
11	90.26	33.19	35.75	26.33	17.43	11.70

Table 3: Fault/100 kM Trending

CONCLUSION

With a structured asset management strategy and initiatives that include Engineering Practices Assessment, CBM regimes and Strategic Spare Management, ageing medium voltage bare overhead lines performance can be improved by rehabilitating the asset installation, monitoring the asset health condition and replacing asset critical components exposed to ageing agents.

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