



TransCo Asset Revaluation 2004

TRANSMISSION ASSET LIVES IN THE PHILIPPINES

- Final
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1. Executive Summary

1.1 General

This report forms part of SKM’s studies for the ODRC Revaluation of the Transco Transmission Network. It details the age profiles which have been determined for the Asset Classes, and describes the process by which a Standard Economic Service Life has been established for each Asset Class

1.2 Asset Standard Economic Lives

SKM has determined, following a detailed study of conditions in the Philippines, exhaustive site inspections, discussions with TransCo senior personnel and study of TransCo documents, that the following Standard Economic Lives are appropriate for the purposes of this ODRC Revaluation.

Category	Description	Life (years)	Notes
Transmission Lines			
	Lattice steel tower line	50	
	Wood pole line	30	
	Concrete pole line	50	
	Steel pole line	50	
Power cables			
	Submarine HVDC	35	
	Submarine HVAC	35	
	Buried HVAC	45	Not applicable
Outdoor Substations -MEAs			
	Transformers 500 kV	45	N-1 security
	Transformers 230 kV	35	Without N-1 security
		45	With N-1 security
	Transformers 115 kV	35	Without N-1 security
		45	With N-1 security
	Reactors	35	
	Capacitor banks	40	
	Outdoor switchbays	40	500 kV, 230 kV, 138/115 kV, 69 kV outdoor assemblies (see Note 1)

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	Substation establishment assets	50	See Note 2
Outdoor Substations-individual equipment			
	Circuit breakers	40	500 kV, 230 kV, 138/115 kV, 69 kV
Indoor GIS Substations			
	500 kV GIS switchbay	45	
	230 kV GIS switchbay	45	
	115 kV GIS switchbay	45	
Substations secondary			
	Protective relays and controls	20	
	Metering equipment	30	
	RTUs, SCADA systems	15	
Communications	OPGW links	50	
	PLC links	35	
	Radio links		
System Control		15	

Notes:

1. A switchgear bay includes the primary equipment, buswork, foundations, equipment supports and other structures, protective and control equipment and cabling directly associated with the bay

2. Substation establishment assets include earthworks, roads, fencing, drainage, earth grid, auxiliary AC and DC power supplies, batteries, cabling not specific to a bay, auxiliary mechanical services, protection and control equipment not specific to a bay

In order to recognise that older equipment which is still in serviceable condition has an economic value greater than zero, we have treated those as having a residual value based on a remaining life of five years.

1.2 Asset Age Profiles

Age profiles for each class of asset have been based on the following reliable sources of information:

Transmission Lines:

- Original construction drawings
- Tower identification plates/stamps

Substation Equipment

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- Original construction drawings
- Nameplates on transformers
- Nameplates on circuit breakers

Cross checking of the various information sources includes the following:

- Manufacturing dates of equipment from TransCo field test reports vs inspection data
- Construction dates of transmission lines vs construction dates of connected substations
- Historical contract data on upgrade projects
- Fixed Asset Register
- Comparison of age profiles for transmission lines, transformers and switchyard equipment.

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2. Introduction

2.1 General

This report forms part of SKM’s studies for the ODRC Revaluation of the Transco Transmission Network. It details the age profiles which have been determined for the Asset Classes, and describes the process by which a Standard Economic Service Life has been established for each Asset Class

2.2 Methodology

It is SKM 's experience that worldwide, there is not universal consistency in the adoption of a standard set of asset class lives, either for accountancy or regulatory purposes.

SKM has however conducted ODRC transmission asset valuations in a number of countries over at least 15 years, and has developed a detailed understanding of the factors affecting the economic life of transmission assets. Our starting point for this study is the tabulation shown in Table 2.1, which shows the range of economic lives for the various Asset Classes which have been widely used elsewhere for ODRC Valuations of transmission assets in both temperate and tropical climates.

Table 2.1 – Typical Ranges of Standard Asset Class Lives

Asset Class	Range of Class Lives (yrs)
Transmission Lines - Steel Tower	55 - 60
- Steel Pole	55
- Concrete Pole	55
- Wood Pole	45
Transmission Cables	40 - 45
Substation Switch bays	45-50
Substation Establishment	50 - 60
Power Transformers	45 - 50
Capacitors	40
Circuit Breakers	45
Current Transformers	45
Voltage Transformers	45
Control & Protection Schemes	15 - 30
SCADA Systems	15
Communications Equipment	10 -12.5

The values in Table 2.1 assume that assets are maintained in accordance with industry standards and manufacturers’ recommendations.

SKM’s methodology may be summarised as follows:

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1. To study in some detail the relevant conditions in the Philippines which have a bearing on the economic lives of transmission lines and substation equipment;
2. To research international experience on the impacts of similar conditions elsewhere; and
3. To apply the outcomes of the above studies to refine Table 2.1 appropriately.

It should be noted that the Standard Economic Life of any Asset Class is an average value for that asset class across the entire network, and cannot be applied with even moderate accuracy to any single asset as an indication of its expected service life.

2.3 Site Inspections and Discussions

In order to achieve a better understanding of the characteristics of Transco's transmission network, SKM specialist engineers have visited the following Transco substations :

- Balintawak
- Araneta
- San Jose
- Sucat

The SKM/CAI team has visited every substation owned and operated by Transco, and has conducted inspections of transmission lines at randomly selected locations. Asset condition has been discussed at every opportunity with substation operating personnel, and visual inspection of all major substation plant conducted at each substation visited. We have also generated an extensive photographic record of substation and lines inspected.

We have also been assisted by discussions with Transco's planning engineers and operation and maintenance personnel, who have also provided details of:

- Equipment ages and load profiles;
- Routine Maintenance Schedules (pre and post 2004) and practices;
- Typical test reports for routine field tests; and
- Generic equipment faults experienced in the Philippines.

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3. Main Factors Determining Economic Service Lives

3.1 Climatic Factors

The tropical climate of the Philippines is the major factor which tends to reduce service lives of transmission assets when compared with those of the same asset types if operating in temperate climates. The climatic environment of the Philippines is characterised by high ambient temperatures, high humidity, high rainfall in the wet season, high winds in the typhoon season, high incidence of lightning, and seismic activity.

This tropical environment produces the following stresses on high voltage electrical equipment:

- accelerated degradation of transmission line conductors resulting from higher ambient temperature and humidity;
- Increased rate of corrosion of galvanised steel structures due to the high time-of-wetness (TOW), especially near the coast;
- Rapid temperature cycling of electrical enclosures associated with tropical thunderstorms;
- Higher ambient temperatures which lead to higher insulation temperatures in transformers and hence a higher rate of degradation of the paper insulation;
- Lowered efficiency of transformer conservator breathers, necessitating additional maintenance effort to limit moisture ingress;
- Higher rate of moisture ingress into oil-immersed post instrument transformers through imperfect seals;
- Increased stressing of insulation because of high lightning incidence; and
- Effect of earth tremors in increasing mechanical stresses in the more fragile items of plant such as transformers and insulator stacks.

In urban and industrial areas having high soot levels in the air, there is a greater incidence of insulator and bushing flashovers, which cause additional stresses on electrical equipment due to fault currents. In geothermal areas, increased sulphide content in the atmosphere tends to increase the rate of corrosion.

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It follows from the above discussion that a higher level of maintenance is required in the Philippines than would be the case in a temperate climate if similar equipment service lives are to be achieved.

3.2 TransCo Network Design Standards

The extent of redundancy of major plant, which reduces thermal loadings under normal conditions and thereby lowers average operating temperatures, has an influence on the expected service life of equipment such as transformers.

Whilst 500 kV/230 kV substations have in the past been designed for N-1 security, 230/115 kV, 115/69 kV and 230/69 kV substations have not been so designed. In the latter cases, substation transformers are at greater risk of significant periods of overloading, during which accelerated ageing of the insulation occurs.

TransCo has advised that a program is in place for the gradual increase of major plant redundancy in 230 kV and 115kV substations. This will be carried out on an opportunity basis as transformers are replaced for reasons of load growth.

3.3 Transco Maintenance Standards

In March 2004, Transco adopted a rigorous maintenance policy based on improved reliability standards, utilising Reliability-Centered Maintenance (RCM). SKM has studied current maintenance schedules and has formed the view that good practices are being followed.

Prior to 2004, Transco maintenance managers have advised that similar procedures were used for routine inspection and testing as at present, but that condition monitoring effort was less appropriately directed than is now the case.

From inspection of test records, limited site inspections and discussions with maintenance managers from the Luzon regions, SKM believes that Transco maintenance standards compare well with those of other countries, and that for the purposes of this revaluation the economic service lives should reflect this fact.

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4. Transmission Lines

4.1 General

In temperate zones, and in the moist tropical climate of northern Queensland, a standard economic life of 50 years has been justified for transmission lines having galvanised steel towers and ACSR conductor.

Transco's transmission lines have been constructed over the period from 1955, and thus have ages varying from 52 years (Binga-San Manuel 230 kV, Balintawak-Duhat 230 kV, Bauang-La Trinidad 230 kV) to less than 5 years. They are predominantly of galvanised steel lattice tower construction.

Transco aerial inspection reports indicate that the towers and conductors of the above ageing lines are still in serviceable condition.

4.2 Factors Determining Economic Service Lives

The major factors which dictate transmission line service lives (other than *force majeure* events such as typhoons and earthquakes) are as follows:

- Corrosion of galvanised steel structures;
- Corrosion of steel cores in ACSR conductors;
- Degradation of concrete foundations; and to a lesser extent
- Galvanic corrosion of pins in strain insulator strings.

4.3 Galvanising of Steel Structures

Components for steel towers and poles on significant Transco transmission projects have in the past been fabricated and galvanised overseas prior to delivery to site in the Philippines.

Transco's standard specification for steel towers requires that all structural steel be hot-dip galvanised to ASTM A123 after preparation in accordance with ASTM A143. The zinc coating is tested to ASTM A239 requirements. Table 1 of A123 requires a minimum average coating thickness of not less than 100 um for structural shapes and plates, and a minimum local thickness of not less than 85 um.

Zinc coatings on exterior galvanised structures owe their high degree of resistance to atmospheric corrosion to the formation in moist air of a protective carbonate film which is relatively insoluble. Environmental conditions which interfere with the formation of this film result in an increased rate of corrosion of the zinc coating.

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The most important factors that control the rate of corrosion of zinc coatings are:

- The duration and frequency of moisture (i.e. time of wetness)
- The rate at which the surface dries
- The extent of pollution of the atmosphere (especially marine chlorides, and also sulphates in industrial and geothermal areas.)

The effect of chlorides and sulphates in the atmosphere is to break down the protective carbonate layer, creating instead zinc chloride and zinc sulphate, both of which are soluble.

Published test reports on corrosion impacts in Thailand environments similar to those of the Philippines (see Appendix 5) have indicated the following annual corrosion rates of zinc coatings:

Bangkok (5 urban/industrial sites): 0.7 to 1.3 um per year, average 1.0 um per year

Samutprakan (1 industrial site): 1.5 um per year

Rayong(1 marine/industrial site): 2.6 um per year

Phuket (1marine site):1.9 um per year

In all cases the test samples were plates exposed on a rack at a 45 degree angle and facing south.

Similar tests carried out in Vietnam have shown a similar range.

Using a conservative corrosion rate of 1.5 um per year for non-marine environments, a zinc layer of 85 um thickness has an estimated life of 57 years. For lines close to the sea shore, a corrosion rate of 2.5 um per year yields an estimated life of 34 years.

SKM's structural engineers in the Manila office confirm that 50 years is a realistic life for lattice transmission towers in the Philippines, except in geothermal regions and where very close to the sea shore. The main points of corrosion on these structures are locations where water can pool; this can only be dealt with by periodic painting with zinc rich paint. The pooling of water can be a problem in the cooler mountain areas even in the dry season because of dew condensation.

4.4 Corrosion of Steel Cores in Conductors

The economic life of ACSR conductor is influenced by two main mechanisms of deterioration:

- Loss of strength of conductors due to corrosion of the steel core;
- Wind-induced damage (applies to multiple conductor bundles only).

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Transco's standard specification for ACSR conductor requires as follows:

- The conductor shall be manufactured to ASTM or IEC Standards;
- Where so specified, the conductor shall be protected by a high melting-point, neutral, organic corrosion inhibitor (*usually provided in the form of grease*). This inhibitor may be applied to the steel core only, or to the entire conductor, as specified for individual projects.

The literature indicates that ACSR designs which incorporate full conductor greasing have been available since approximately 1965, and that prior to that date it was the normal practice to grease only the steel core, in order to inhibit galvanic corrosion between the galvanising of the steel core and the aluminium of the overlying conductor strands. It is therefore expected that the abovementioned ageing 230 kV lines were built using ACSR conductor with core-only greasing; Transco has confirmed that this is the case.

SKM's international experience is that ACSR conductor with core-only greasing has a service life of 45 to 50 years, even in tropical conditions. This has been found to be the case in regions ranging from the cool climates of Canada, UK, New Zealand and southern Australia to the tropical climates of Singapore and northern Australia.

4.5 Degradation of Foundations

Transco engineers have advised that for one of the above mentioned ageing 230 kV lines (which traverses steep terrain), it has been necessary to reinforce some of the foundations due to instability of the soil; the others are thought to be in satisfactory condition.

4.6 Summary

On the basis of the satisfactory present condition of 260 km of 230 kV line located in North Luzon and constructed between 1955 and 1957, the above-mentioned published test reports on corrosion of zinc coatings, and SKM's own site inspections, an economic service life of 50 years is considered reasonable for transmission lines using galvanised steel towers and ACSR conductor.

The 138 kV transmission system in Mindanao appears to date from only 1977; that in Visayas from 1983. No conclusions can be drawn from inspection of these comparatively young assets.

4.7 Age Profiles

Age profiles were developed for transmission and subtransmission lines in the Luzon, Visayas and Mindanao regions. These profiles have been used for consistency checks against the proposed asset age for transformers and for switchyard equipment.

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5. Transmission Substations – Power Transformers

5.1 General

In temperate zones (latitudes between 30 and 40 deg.C) a Standard Economic Life of 45 to 50 years has been justified for power transformers in transmission substations which have been designed for N-1 level of security.

Transco's transformers vary in age from 50 years to less than 5 years, although there are few with ages of more than 30 years. They have been manufactured by a variety of European, Japanese, US and other suppliers.

The end of a transformer's service life, and hence its economic life, is commonly taken to be the time at which the paper insulation of the windings has aged and lost strength sufficiently that the transformer has lost its capability to withstand the forces associated with a through fault. Unfortunately for individual transformers this point in time is difficult to determine.

The ageing process of transformer insulation is accelerated by two main factors:

- Increased winding temperatures;
- Ingress of moisture from the external atmosphere via the mineral oil in which the windings are immersed.

5.2 Transformer Operating Temperatures

5.2.1 Transformer Design Standards

International Standard IEC 76-1 specifies design temperature rise limits for oil-immersed power transformers at rated continuous loading as follows:

- Top oil temperature: 60 deg.C
- Average winding temperature, as determined by resistance measurement: 65 deg.C

These limits are applicable under the following reference conditions:

- Maximum ambient temperature of 40 deg.C
- Maximum monthly average ambient temperature not exceeding 30 deg.C
- Annual average ambient temperature not exceeding 20 deg.C
- Transformer cooling systems ON or OF (i.e. not OD)

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For Manila (latitude 14.5 deg.N), the meteorological records indicate as follows:

- Maximum ambient temperature of 40 deg.C
- Maximum monthly average ambient temperature: 34.5 deg.C (which exceeds the IEC limit)
- Annual average ambient temperature : 26.9 deg.C (which exceeds the IEC limit)

In accordance with IEC 76-1, the temperature limits for Philippines transformers must be reduced from the standard values (60 and 65 deg.C) to the reduced values of 53 deg.C (top oil temperature) and 58 deg.C (average winding temperature).

The corresponding maximum temperatures for continuous operation become:

- Top oil temperature : $53 + 40 = 93$ deg. C
- Average winding temperature, as determined by resistance measurement: $58 + 40 = 98$ deg.C

5.2.2 Effect of Climatic Differences

The above value of 45 to 50 years applies to transformers which rarely operate at more than 2/3 continuous rating because of the N-1 redundancy of station design. This performance is achieved with a typical yearly average (24-hr) ambient temperature of 17.6 deg. C (Sydney, latitude 34 deg.S), a average maximum temperature reaching 26.1 deg. C in summer, and with design limits for average winding temperature rises at 65 deg. C. The ambient temperature conditions meet the reference conditions of IEC 76.1 and hence there is no derating factor to be applied to the nameplate continuous MVA rating.

Cooling systems in the temperate zones of Australia are designed for ONAN/ OFAN/ OFAF operation (i.e. one stage of forced air cooling plus forced oil circulation)

In the Transco network, a similar N-1 design philosophy is followed for 500 kV transformers. The average ambient 24-hr temperature is 26.9 deg. C. The average maximum temperature reaches 34.5 deg. C in May. Design winding temperature rises are 65 deg.C and cooling systems are specified to use two stages of forced air cooling but not forced oil circulation (i.e. ONAN/ONAF1, ONAF2). The ambient temperature conditions do not meet the reference conditions of IEC 76.1 and derating is applicable (see 5.2.1 above); however the reduced loadings which are applicable under N-1 conditions ensure that for most of a transformer's life, winding temperatures will not exceed the limiting value of 98 deg.C. Reduction of transformer life on account of temperature is therefore not expected.

However in the case of 230 kV and 115 kV transformers where N-1 design philosophy does not apply, the reduction in life because of the ambient temperature effect will be accentuated because of their more severe (non-N-1) loading regimes. From the above, it is apparent that a transformer winding temperatures in the Philippines will on average be about 7 deg.C higher than that of an IEC 76-compliant transformer, e.g. a similarly loaded transformer of the same rating in a temperate country (see calculation in Appendix 4). This difference will tend to reduce the operational life of

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the paper insulation of the Philippines transformer by a calculated 50%. A cautious interpretation leads to the conclusion that this Arrhenius effect could reasonably be expected to reduce a 45-year life by 25% to 35 years.

5.3 Moisture Ingress into Transformer Insulation

A second major factor influencing transformer life is the ingress of moisture through imperfect drying devices, usually of the silica gel type. Excessive moisture in the paper insulation acts to accelerate the ageing process. In severe cases the evolution of vapour bubbles from the insulation can lead to insulation failure.

Transco's power transformers are specified to have each conservator chamber fitted with two parallel silica gel breathers, fitted with valving which enables either to be switched to 'duty' mode and the other taken out of service. To allow for the high humidity, which adversely affects the efficiency of the silica gel, breathers are specified to be larger than normal and to be fitted with oil traps. Silica filling capacities are specified to be:

- 3 kg. for OLTC conservators;
- 4 kg for main conservators on transformers up to 25 MVA, 6 kg for transformers up to 100 MVA, 8 kg for transformers above 100 MVA.

This approach is expected to be satisfactory provided that the necessary maintenance effort is put into drying of the silica gel. SKM's site inspections tend to indicate that maintenance in this respect is good, although it must be stated that these inspections took place at the end of the dry season.

It is noted that TransCo's standard periodic field test data for transformers does not include measurement of water content in the oil. Dielectric testing of the oil and DGA analysis are, however, included.

5.4 Summary

The main causes of reduced transformer life in tropical climates like that of the Philippines are:

- Higher insulation temperatures due to higher ambient temperatures;
- Greater level of moisture ingress through imperfect breathers.

For N-1 substations, we have assigned a standard economic life of 45 years for power transformers on the basis of good quality maintenance practices.

For non N-1 substations, in which the higher average insulation temperatures of transformers is not compensated for by lower MVA loadings, we have assigned a Standard Economic Life of 35 years.

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5.5 Age Profiles

The age profiles of N-1 and non-N-1 transformers were developed at various voltages in the Luzon, Visayas and Mindanao regions.

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6. Transmission Substations – Outdoor Switchgear

6.1 General

In temperate zones, and also in the moist tropical climates of Singapore and of northern Queensland, a standard economic life of 45 years has been justified for outdoor circuit breakers in transmission substations.

Transco’s 500 kV, 230 kV and 115 kV outdoor circuit breakers vary in age from 30 years (69 kV) and 25 years (115 kV and 230 kV) to less than 5 years. The oldest are of the bulk oil type and there are some air blast breakers but (significantly) the majority are of the SF6 type. Dead tank circuit breakers constitute about 30% of the SF6 total, and live tank circuit breakers some 70%.

SF6 circuit breakers are dependent on the integrity of the gas volume of each pole for satisfactory operation over a service life which manufacturers claim exceeds 30 years. Maintaining the integrity of the gas volume requires the ability to:

- Maintain sealing of the gas volume over the service life;
- detect loss of pressure of the gas;
- neutralise the effects of moisture and decomposition products of the gas.

Perusal of Transco’s document “Standard Technical Specifications – Design, Furnishing and Installing, Testing and Commissioning of Substation Project” Section indicates the following environmental requirements:

- a seismic capability of not less than 0.4g (4.0 m/sec/sec) as per the Philippines Building Code;
- A design wind speed of 250 km/hr (Zone 1 Eastern Luzon), 200 km/hr (Zone 2 Western Luzon, Visayas and northern Mindanao) and 125 km/hr (Zone 3 southern Mindanao) as per the Philippines Building Code.

However it is understood that other Transco specifications have specified a design wind velocity of 270 km/hr in Luzon, 185 km/hr elsewhere throughout the Philippines, and a seismic capability of 0.3g in Luzon and Visayas (0.2g in Mindanao).

Standard manufacturer designs for circuit breaker stacks are based on a maximum wind velocity of only 125 km/ hr. For the purposes of this ODRC valuation, it has been assumed that all switchyard equipment has been supplied, mounted and supported such that local maximum wind speeds can be withstood without adverse effect.

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6.2 Ambient Conditions

SF6 circuit breakers are commonly designed for a maximum ambient temperature of 40 deg C. They can be stressed by the rapid changes in temperature which occur at the onset of tropical rainfall. Otherwise, because each pole of these circuit breakers is completely filled with SF6 gas under pressure in a sealed enclosure, their functioning is not effected by humidity or rain so long as gas volume has not been lost due to leakage.

Atmospheric pollution is normally not a problem so long as the insulator creepage distance is selected for the 'heavy' (25 mm/ kV) or 'very heavy' (31 mm/kV).

6.3 Maintenance Requirements

Maintenance requirements for sealed SF6 circuit breakers are low, the design service life (as conservatively stated by the manufacturer) being typically 30 years+ or 10,000 mechanical operations. However, other than inspection and lubrication of the operating mechanism, little is needed until timing tests and contact resistances would normally be carried out after about 5 fault interruptions.

6.4 Seismic Loadings

The mechanical stress on a live tank circuit breaker due to earthquakes is most severe at the bases of the support stacks. Standard versions of live tank circuit breakers made by major manufacturers can normally withstand seismic accelerations of up to 0.3g (3 m/sec/sec) which is insufficient to meet Philippines structural standards (0.4g). For greater seismic loadings it is necessary to employ a reinforced support structure, reinforced insulators or earthquake dampers.

It has been assumed for the purposes of this ODRC valuation that all switchyard equipment has been supplied, mounted and supported as necessary to withstand the Philippines structural standards.

6.5 Summary

SKM has selected a Standard Economic Life of 35 years for outdoor switchgear.

6.6 Transco Age Profiles

Age profiles of Transco's outdoor circuit breakers were developed from data extracted from the nameplate details captured during site inspections.

Because of the close correlation between circuit breakers and their associated disconnect switches and instrument transformers, these age profiles have been assumed to apply also to those asset classes.

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7. Transmission Substations – Indoor GIS Switchgear

7.1 General

In temperate zones, and in the moist tropical climate of Singapore and of northern Queensland, a standard economic life of 45 years has been justified for indoor GIS switchgear in transmission substations.

TransCo's 500 kV, 230 kV and 115 kV GIS installations are limited to three locations:

- San Jose Substation (500 kV, 1999)
- Araneta Substation (230 kV, 1997 and 115 kV, 1997)
- Zapote Substation (230 kV, 2001)

In all cases the GIS system has been selected by the designers because of space limitations at the site (Araneta, Zapote), or in order to avoid costly additional civil works (San Jose).

We have been advised by Transco operations engineers during a visit to Araneta and San Jose that no problems have been experienced to date with the GIS equipment at those stations other than a very small loss of gas in the Araneta 115 kV equipment. The regular inspection and maintenance regime at those stations appeared good by industry standards, well organised and carried out by TransCo's own personnel.

7.2 Ambient Conditions

GIS switchgear is installed indoors and is thus protected from rapid changes in temperature, from solar loadings, and from rain. Being contained within high conductivity aluminium enclosures, any corrosion processes are minimised.

Thus the climatic stresses that are experienced by outdoor HV switchgear are not experienced by indoor GIS installations.

7.3 Ingress of Moisture

GIS switchgear and buswork is filled with SF₆ gas at positive pressures of 400 to 500 kPa (4 to 5 bars) and is sealed from the external atmosphere such as to prevent gas leakage. This sealed and pressurised system is inherently proofed against the ingress of atmospheric moisture during normal operation. Routine maintenance tasks are carried out via automatic vacuum couplings

7.4 Maintenance Requirements

Routine maintenance is required only at approximately 5-yearly intervals, and involves checking gas quality, hydraulic fluids and enclosure lubrication.

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The maintenance load on Transco of this type of equipment is light.

7.5 Seismic Loadings

Major GIS switchgear manufacturers have standard equipment which has withstood seismic tests of 1.0g (9.8 m/sec/sec).

7.6 Summary

It is SKM's view that well-designed and well-installed assemblies of GIS switchgear, if properly monitored and maintained, should have a service life not less than that of outdoor SF6 switchgear of the same voltage class. For that reason we have assigned a Standard Economic Life of 45 years for the purposes of ODRC Valuation.

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8. Transmission Substations – Other Switchyard Equipment

8.1 Instrument Transformers

The standard economic service life of outdoor gas-insulated post-type instrument transformers has been selected to match that of live tank SF6 circuit breakers, i.e 40 years. For the oil-immersed post type, which constitute the majority of instrument transformers on the Transco network, a we have selected a value of 35 years because of its higher susceptibility to moisture ingress through imperfect seals.

Transco engineers have confirmed that seal failure is a significant problem with post-type current transformers and voltage transformers. Given the high rainfall and rapid temperature cycling undergone by these devices in the tropical environment, we believe it to be a reasonable expectation that their average economic lives are lower than would be the case in a temperate climate.

The economic life for instrument transformers has been taken into account in determining the life for a substation bay.

8.2 Capacitor Banks

Capacitor banks are assemblies of sealed capacitor cans (the enclosures usually of stainless steel), aircored reactors and circuit breakers or oil-immersed switches.

Capacitor failure is usually limited to the intermittent failure of individual cans, which are replaced upon failure from spares holdings.

Because of the variety of equipment comprising a capacitor bank, SKM has selected for Standard Economic Life a value of 35 years , as for outdoor switchgear and other switchyard equipment.

8.3 Reactors

The standard economic service life for 230 kV and 115 kV reactors has been selected to match that of non-N-1 transformers, i.e 35 years.

8.4 Disconnect Switches

TransCo's substations contain a wide variety of types and makes of disconnect switches. Our assessment of a suitable economic life for this class of assets is based on the condition of 230 kV disconnect switches at the older substations Balintawak (1956),

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Binga (1956), San Manuel (1956), Mexico (1956), Bauang (1956), and La Trinidad (1956).

SKM's inspections and discussions with maintenance personnel indicate that these are simple and robust mechanical devices, the main source of trouble being burned contacts. Replacement contacts are not always available for all types of disconnect switches.

The economic life for disconnect switches has been taken into account in determining the life for a substation bay.

8.5 Surge Arresters

International practice is to replace surge arresters after 25 to 30 years of service because the risk of short circuit failure increases with age. Transco has no specific guidelines in this respect.

The economic life for surge arresters has been taken into account in determining the life for a substation bay.

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9. HV Power Cables

9.1 General

Transco owns and operates one submarine DC link (Leyte- South Luzon 230 kV, 200 MVA, installed in 1998) and six submarine AC links, amounting to some 100 km of undersea AC and DC power cables. On land, the use of underground power cables is avoided wherever possible and it is believed that the small quantities are not material for the purposes of this revaluation.

9.2 Submarine Power Cables

Submarine cables, because of their special individual requirements, are normally designed and manufactured on a project-by-project basis by specialist manufacturer/installers.

The following types of cable are in use:

- Extruded XLPE-insulated cable, which has been developed from the early 1970's, has a proven life (according to at least one manufacturer) in excess of 30 years. It is most suited to AC links for voltages up to 200 kV and 300 MVA, is mechanically robust for installation, and the extrusion process minimises the need for cable joints. It has also been used for DC links up to 150 kV and 500 MW over long distances.
- Mass-impregnated paper insulated (MIND) cable, which has been in use for the last 80 years, is suited to very long links for DC voltages of up to 500 kV and 800 MW. Its first use for undersea DC links was in 1954 (replaced in 1973). Manufacture is slow and it is not so mechanically robust during installation.
- Oil-filled (LPOF) cable, which is suited to high capacity medium length AC and DC links. This type, which also uses paper insulation, is used up to 600 kV and 1000 MW for DC links, and up to 500 kV, 1000 MVA for AC links.

SKM has assigned a Standard Economic Life of 35 years to all three types of cable.

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10. HV Converter Stations

The Transco network includes one DC link, which interconnects Luzon (at Sorsogan Converter Station) and Leyte (at Ormoc Converter Station). Each converter station is fed at 230 kVAC from three 172 MVA single transformers and transmits power via a monopolar submarine cable link which operates at 350 kVDC. A spare cable is installed. The converters are of the 12-pulse type and the DC outputs are smoothed by harmonic filters. This HVDC link was commissioned in 1998.

SKM has assigned a Standard Economic Life of 30 years to these converter stations.

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11. Transmission Substations – Protection and Control Equipment

11.1 General

In various countries, located in both temperate and tropical zones, a standard economic life in the range 15 to 30 years has been justified for protective relay and control equipment, the selected value for any given valuation being in accordance with the following considerations:

- The performance under test of older types of relays;
- The effect of technical obsolescence;
- The replacement policies of the owner.

Transco’s transmission substations contain a wide range of protective relay types, from the electromechanical types of the 1950s and 1960s through the discrete electronic types of the 1970s and 1980s to the modern multifunction digital types of today.

Unlike the replacement of primary plant, which has retained its historical functional building blocks (transformers, circuit breakers etc.) the protection, instrumentation and control asset categories have in recent years undergone a quantum leap in their structure. Modern microprocessor-based protective relays haven proven their reliability and, in addition, have taken on the metering, control, fault recording and data communications functions which used to be carried out by separate metering, control and recording devices.

The recent rate of technology change is not likely to fall in the next decade, and electricity transmission and distribution companies have a difficult task in deciding how to plan upgrade works on their protection and control systems. In the future, ageing protective relays will not be replaced by functionally similar devices as modern equivalents will not be available. Thus replacement works will be done on a larger scale and many ‘young’ items of equipment will be replaced early because of the changing functionality.

11.2 Summary

Because of the rapid rate of technical obsolescence in this field, it is expected that most existing protective relays, control systems and instrumentation will be replaced within the next 15 years, regardless of the year in which they commenced service.

Whilst the concept of a Standard Economic Life is not altogether appropriate for these obsolescent assets, the ODRC methodology requires that a value be nominated. SKM has adopted a value of 20 years for the purposes of this ODRC revaluation.

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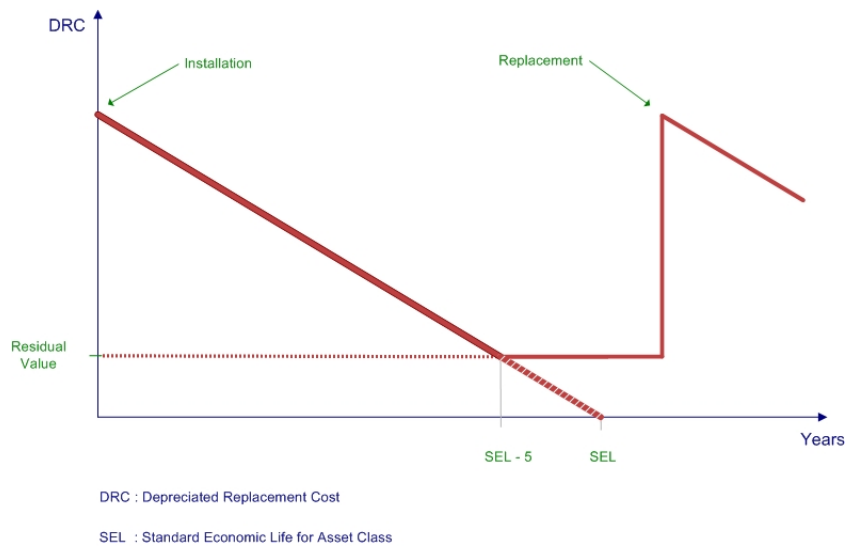
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12. Residual Asset Lives

Because the Standard Economic Life which has been applied to each Asset Class is an average across the TransCo system, there are a significant number of assets which are older than the standard value for their respective classes but which are still serviceable. The replacement values of such assets have not been depreciated to zero but in accordance with Fig. 12.1 below, in order to recognise a residual value corresponding to five years of remaining service life.

Fig 12.1: Principle of Residual Values



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13. Summary and Conclusions

Sinclair Knight Merz has determined, by means of the reasoning detailed in Sections 2 to 12 that for the purposes of this ODRC valuation, the Standard Economic Lives for the transmission asset classes shown in Table 13.1 below are reasonable.

Table 10.1 Recommended Economic Service Lives for Transco Transmission Assets

Category	Description	Life (years)	Notes
Transmission Lines			
	Lattice steel tower lines	50	
	Wood pole lines	30	
	Concrete pole lines	50	
	Steel pole lines	50	
Power cables			
	Submarine HVDC	35	
	Submarine HVAC	35	
Outdoor Substations -MEAs			
	Transformers 500 kV	45	N-1 security
	Transformers 230 kV	35	Without N-1 security
		45	With N-1 security
	Transformers 115 kV	35	Without N-1 security
		45	With N-1 security
	Reactors	35	
	Capacitor banks	40	
	Outdoor switchbays	40	500 kV, 230 kV, 138/115 kV, 69 kV outdoor assemblies (see Note 1)
	Substation establishment assets	50	See Note 2
Outdoor Substations- individual equipment			
	Circuit breakers	40	500 kV, 230 kV, 138/115 kV, 69 kV
	Converter equipment	30	
Indoor GIS Substations			
	500 kV GIS switchbay	45	
	230 kV GIS switchbay	45	

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	115 kV GIS switchbay	45	
Substations secondary			
	Protective relays and controls	20	
	Metering equipment	30	
	RTUs, SCADA systems	15	
Communications	OPGW links	50	
	PLC links	35	
	Radio links		
System Control		15	

Notes:

1. A switchgear bay includes the primary equipment, buswork, foundations, equipment supports and other structures, protective and control equipment and cabling directly associated with the bay
2. Substation establishment assets include earthworks, roads, fencing, drainage, earth grid, auxiliary AC and DC power supplies, batteries, cabling not specific to a bay, auxiliary mechanical services, protection and control equipment not specific to a bay

In order to recognise that older equipment which is still in serviceable condition has an economic value greater than zero, we have treated those assets as having a residual value based on a remaining life of five years.

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Appendix A Geographic Factors Affecting Asset Lives

The following charts, extracted from the National Structural Code of the Philippines, illustrate the Wind Zones and Seismic Zones of the Philippines.

Wind Loading Map

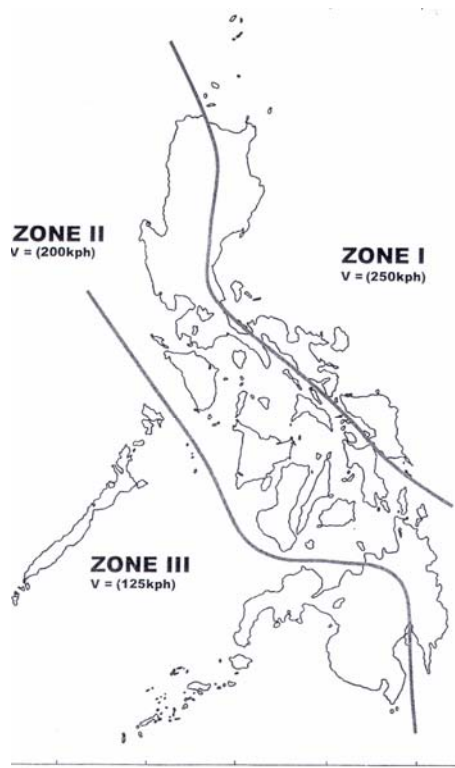


Figure 207-1 Wind Zone Map of the Philippines

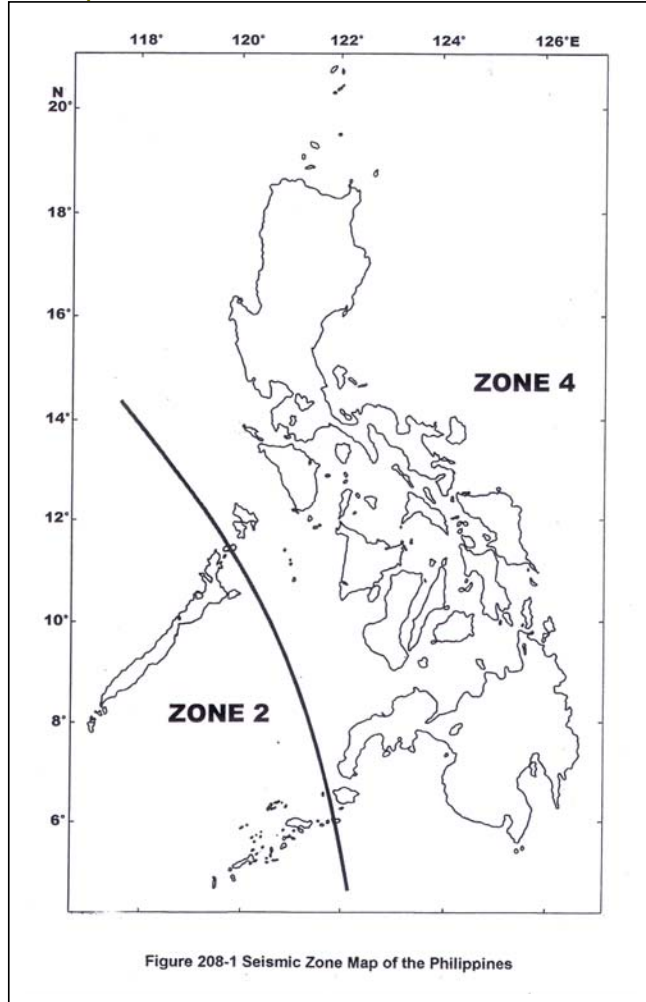
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Seismic Zone Map



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Appendix B Meeting Notes

Notes of Meeting of 8 June 2005 with Arturo Salvamente; Gildo Listano and Jorge Paguio of Power System Maintenance Dept , PWC representatives, G. Nicholas of SKM

Questions on Maintenance of Substation Equipment and Lines *(answers are in italics)*

1. General

- 1.1 Present maintenance and testing procedures look good. Were they as good before 2004 maintenance policy?

The maintenance procedures are basically unchanged but now we have a more rigorous approach to testing and documentation of the results for condition trending. The adoption of RCM means that we test more frequently for suspect and critical equipment and less often for equipment known to be sound. The Maintenance Calendar has been rationalised accordingly.

- 1.2 Which equipment may not have been as well maintained prior to 2004?

Routine transformer DGA testing was not commenced until 1998. All transformers are now tested yearly and suspect units 6-monthly.

- 1.3 What are Transco guidelines for frequency of inspection and routine maintenance on major plant?

As an example, protection relays are performance tested and adjusted yearly, and all transformers DGA tested yearly.

- 1.4 What are triggers for replacement of items of major plant?

Power Systems Maintenance Department makes recommendations for replacement, based on considerations of condition, loading, safety etc. Such a recommendation gets the replacement project on to the capital works project; however it may be up to 2 years before a replacement asset is actually ordered.

- 1.5 What are the main problems caused by corrosion above ground ?

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Corrosion of the galvanising coating on steel structures in atmospheres high in chloride (near the coast) or sulphate (thermal and power station areas), which increases maintenance requirements and reduces life.

1.6 Are there problems caused by corrosion of buried cables, earth grids etc?

Transco uses very few buried power cables, because of the risk of water ingress. Earth grids are of copper conductor.

1.7 What is the impact of typhoons?

A significant reduction in the average life of transmission lines in the East Luzon region.

1.8 How is damage to assets from seismic events minimised?

The last major earthquake was in 1990. Equipment is required to have adequate seismic withstand strength. Transformers are fitted with accelerometers which trip them off during an earthquake in order to minimise the risk of an internal fault.

2. Power Transformers

2.1 What is the approximate age of the oldest 230 kV and 115 kV transformers?

In North Luzon we have some 69 kV transformers dating back to 1952 which are still in service. However at 220 kV and 115 kV the oldest date from the mid 1970s.

2.2 Where are the old transformers located?

North Luzon.

2.3 Are 230 kV and 115 kV transformers subjected to overloads often?

Sometimes. We are gradually trying to improve the level of redundancy to N-1 as for the 500 kV transformers, which will reduce overloads.

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2.4 What is policy for replacement of old transformers? (Now and pre-2004)?

Recommendations by Power Systems Maintenance Department for replacement are made on the basis of transformer condition as indicated by periodic DGA testing. Where possible paper samples are taken every 5 years for polymerisation (DP) tests.

2.5 Are transformer temperatures regularly logged? Who keeps the records?

Transformer temperatures are logged hourly by operators.

2.6 What is the typical range of moisture content in the transformer oil ? What value is considered too high?

When testing indicates that moisture content exceeds 25 ppm, PS Maintenance Dept. recommends vacuum filtering of the oil.

2.7 Is transformer oil vacuum-filtered ? When?

See 2.6 above.

2.8 Is the system of silica gel breathers satisfactory?

Yes

3. Outdoor Circuit Breakers

3.1 What is the approximate age of the oldest 500, 230, 115 and 69 kV outdoor circuit breakers?

In Luzon, the oldest 69 kV breakers are about 30 years old. The oldest 230 kV and 115 kV breakers are about 25 years old.

3.2 Where are the old circuit breakers located?

Dolores and Mexico Substations.

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3.3 Are there any bulk oil circuit breakers still in service? Minimum oil type? Air blast type?

A few only. The majority of 115 kV and 220 kV breakers are of the SF6 type.

3.4 Are there any generic problems with SF6 circuit breakers (seals, gas pressure alarms, etc)

Yes, leaks from gas seals and sticking pressure switches. The European makes (Alstom, Merlin Gerin and Magrini-Galileo) give the most trouble. The American and Japanese makes are better in this respect. Also, the gas compressors in some types (e.g. Nissin) give trouble.

3.5 What factors trigger the replacement of a circuit breaker?

Unsatisfactory IR test results, continuing seal problems, unsatisfactory timing tests

3.6 Are dead tank circuit breakers preferred to live tank breakers? What proportion of 500, 230 and 115 kV breakers are of the dead tank type?

About 30% are dead tank type. The space saving is important

3.7 Do all circuit breakers have anticondensation heaters and/or moisture detectors?

Always. Some breakers also have control cabinets with openable vents.

3.8 Do all SF6 breakers have gas pressure alarms?

Yes.

4. Outdoor Instrument Transformers

4.1 What is the approximate age of the oldest 500, 230, 115 and 69 kV outdoor CTs and VTs

The age profile of CTs and VTs is very similar to that of circuit breakers of the same voltage.

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4.2 Where are the old CTs and VTs located?

As for circuit breakers.

4.3 What are the main types of post CTs and VT/CVTs in service?

Nearly all post CTs are of the oil immersed type. A few are gas-insulated. CVTs are used from 115kV to 500 kV, except for high accuracy metering applications where magnetic VTs are used.

4.4 Are there any generic problems with post CTs and VT/CVTs?

Moisture ingress through seals.

4.5 What factors trigger replacement of a post CT? And a VT or CVT?

Seal problems and consequent loss of bushings.

5. Outdoor Disconnect Switches

5.1 What types of disconnect switch are favoured?

Transco has a mixture of all types (vertical, horizontal, single and double break)

5.2 Are there many old ones still in service?

5.3 What are the main problems?

Contact wear. Spare contacts are not always available.

6. Protective Relays

6.1 Are all protective relays installed in airconditioned rooms?

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Electronic relays are always in airconditioned rooms. The older electromechanical types are not generally in airconditioned rooms

6.2 Are there many old electromechanical relays still in service? Where?

Yes, there are still many in service. But they are tested regularly for correct functioning.

6.3 How often are routine tests carried out on protective relays?

Generally every 12 months

6.4 What factors trigger replacement of an old relay by a new relay?

Changes in coordination design, setting changes due to increases in fault levels, inability to calibrate old electromechanical types.

7. Transmission Lines

7.1 The oldest lines were built in 1956- 1958 (230 kV Ambuklao-Binga, Balintawak- Duhat, Binga –San Manuel, Bauang- La Trinidad). What is their present condition?

-tower corrosion?

Still good.

-Conductor core corrosion?

Not aware of any problems. No conductors have been replaced as yet

-Foundations?

Some have been reinforced, especially on the Binga-San Manuel lines, which traverse steep slopes.

7.2 Can SKM get a condition report from the last inspection?

Transco inspects lines regularly by aerial patrol. The most recent reports for the above lines will be provided to SKM.

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7.3 What is the maintenance policy and schedule of inspections/maintenance for transmission lines?

69 kV lines are inspected every 6 months; higher voltage lines annually. At present there is a 30-year program for the replacement of wooden poles, whose average service life is only 25 years.

8. Underground Cables

8.1 Cables used at which voltages?

Transco has only very small quantities of buried cables on land. Its use is avoided wherever possible because of water ingress risks.

8.2 Any problems experienced?

Notes written by Greg Nicholas, SKM.

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Appendix C Calculations

Calculation of Accelerated Thermal Ageing of Transformer

(For winding temperatures of 105 deg.C (reference) and 112 deg.C (accelerated))

1. Reference temperature $T_s = 105 + 273 = 378$ K

2. Accelerating temperature $T_a = 112 + 273 = 385$ K

3. From Saha, IEEE Transactions on Dielectrics and Electrical Insulation, October 2003,

Insulation life = $k \exp(13600/T)$ for cellulose insulation, where k depends on operating conditions

4. Therefore $T_s/T_a = \exp(13600/378) / \exp(13600/385)$

$$= \exp(36.0) / \exp(35.3)$$

$$= \exp(0.7)$$

$$= 2.01$$

i.e. Accelerated life = 50% of Reference Life.

5. If reference life is 45 years, accelerated life = 22.5 years

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- 2) Atmospheric depositions and Corrosion Impacts in Bangkok (Panther, Hooper et al, CSIRO Australia, 2003)

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