westernpower

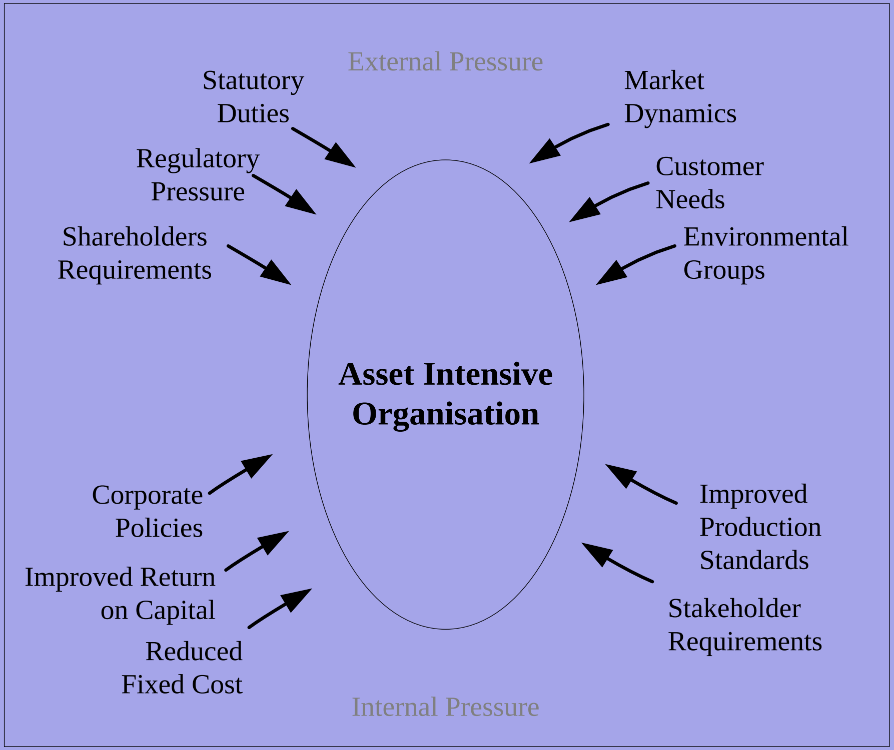
Safe, Reliable, Efficient

Improving Plant Reliability by Addressing Maintainability & Maintenance Requirements

Case Studies

Presented by Zahra Jabiri
AMC – Perth , May 2011
DM#8178554

Introduction



Drivers for change in asset intensive organizations since 1970s.

- Before mid 1970s, most industries had operating and profit margins that were ample enough to accommodate many small failures and an occasional large failure.
- Maintenance workers were largely disconnected from the budget processes and viewed their primary responsibility as repairing failure as quickly as possible. Budgets for equipment maintenance were largely based on prior years' performance. There was little awareness of requirements for improvement or motivation to pursue changes.
- competitive environment in the mid 1970s , and emerged leverage of regulatory compliance, safety and environmental obligations draws attention to a more precise understanding of management of the asset.

Outline

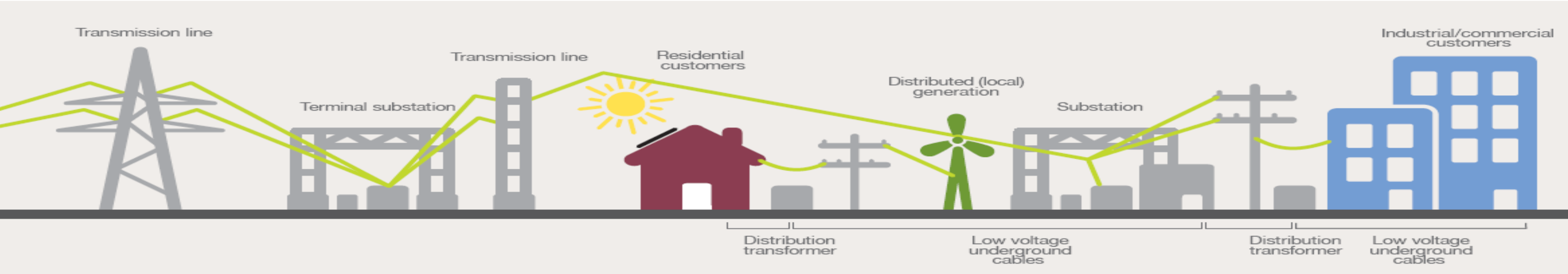
- Western Power
- Western Power's Responsibilities
- Reliability, Maintainability and Maintenance
- Reliability vs. Asset Life Cycle
- Case Studies
- Conclusion

Western Power

A Power Transmission and Distribution Company,

The network stretching from Kalbarri in the north to Kalgoorlie in the east and south to Albany,

Transmission network:
 $3.1 Billion replacement value
100,000 defined assets



Western Power Responsibility

Delivering Safe and Reliable and Efficient Electricity Supply

- Reliability: committed to ensure that the supply of electricity to customers is maintained and the occurrence and duration of power interruptions is kept to a minimum.

- KPI: System Minutes Interrupted for transmission performance.

Reliability , Maintainability & Maintenance

- Reliability : The probability that a system or product will perform in a **satisfactory manner** for **a given period of time**, when operated **under specified operating condition**

Expectations, Requirements , Constraints

Reliability , Maintainability & Maintenance

Maintainability:

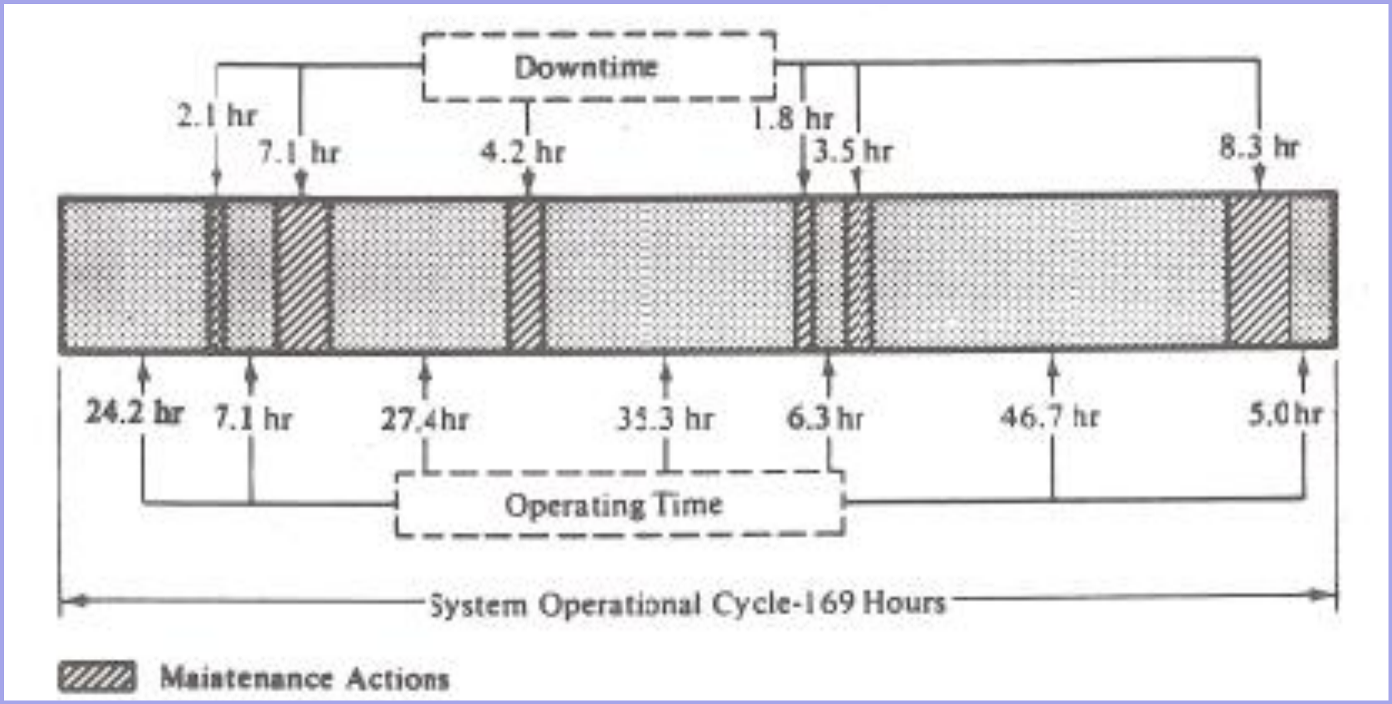
Is a system design characteristic and addresses the ease, accuracy, timeliness, and economy of maintenance action.

Objective:
To influence design and produce/manufacture a product that is effectively or efficiently supportable.

Reliability , Maintainability & Maintenance

- Maintenance: Is performed on a system in the event of a failure, or as a preventive measure to prevent an expected failure .

An example



$$R(t) = e^{-t/MTBF} = e^{-\lambda t}$$

$$\lambda = \frac{\text{number of failures}}{\text{total operating time}} = \frac{6}{152} = 0.03947$$

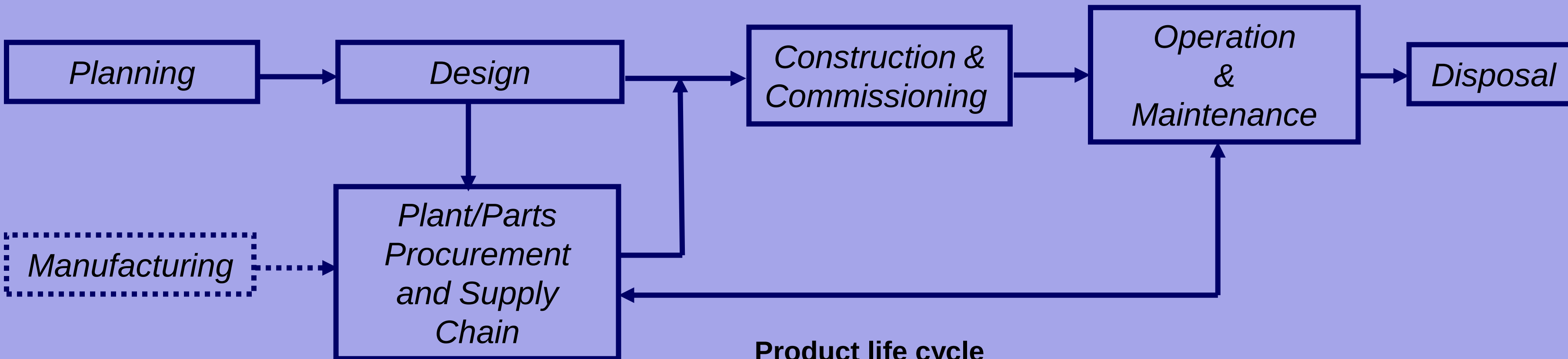
$$MTBF = \frac{1}{\lambda} = \frac{1}{0.03947} = 25.3357 \text{ hours}$$

In determining the frequency of corrective maintenance actions care must be taken to consider the overall failure rate, including failure inherent in design (also called “primary defects”, or “catastrophic” failures, “Secondary” or dependent failures, failures due to introduction of manufacturing defects, and failure introduced by the operators or the maintenance personnel . The objective is to address all factors that may results in an inoperative system.

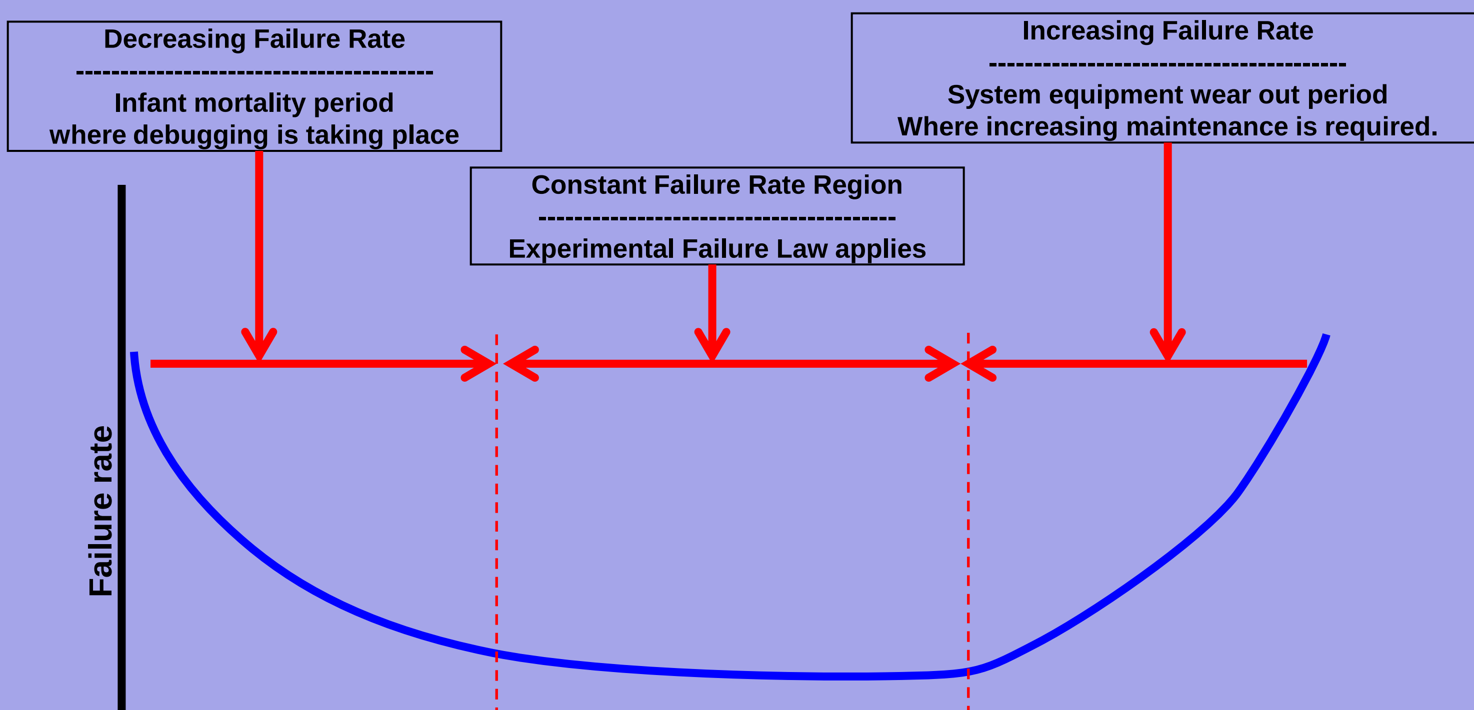
What is FMECA?

- Failure Mode Effect and Criticality Analysis (FMECA): To identify potentially design weakness through a systematic analysis.
- FMECA can be used as “before the fact “ or “after the fact” tool
- FMEAC can be Top-down functional approach or Bottom-up hardware approach.

Reliability vs. Asset Life Cycle



Product life cycle



Bathtub curve based on time dependent failure rate

Where to Start?!

Voice of Business

Voice of Stakeholders

Voice of System/Product

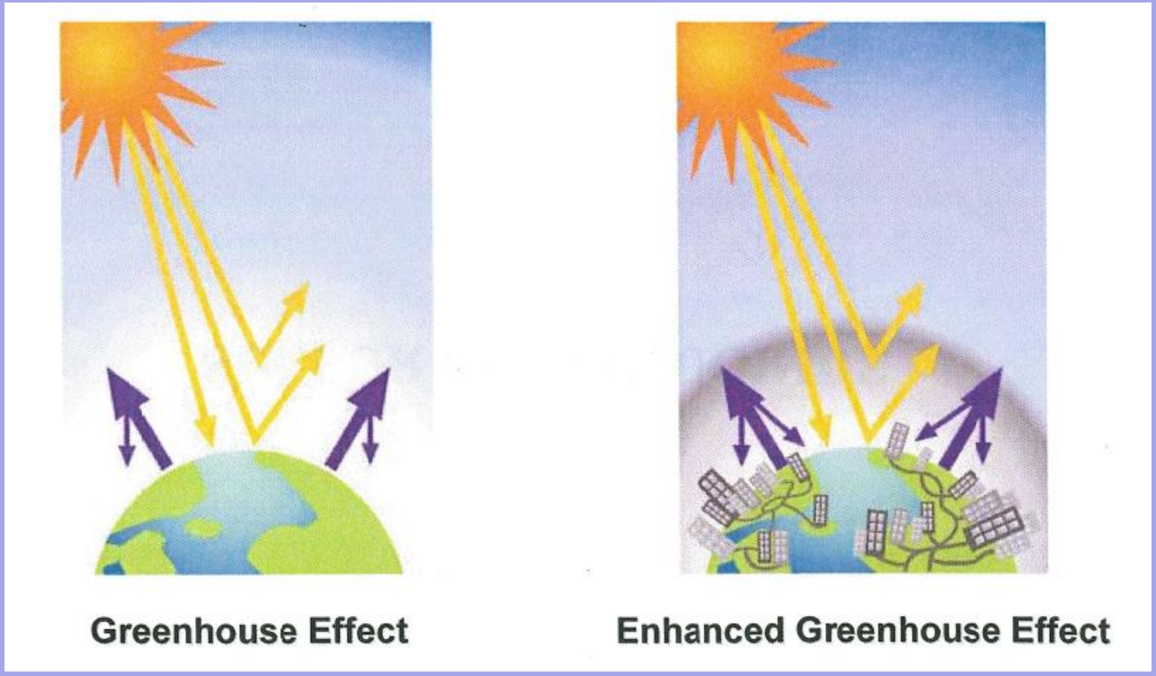
Voice of Process

Case Study 1
SF6 Emission Management

- Environment is becoming an issue for everyone
- Western Power entered an to reduce its greenhouse emission,2006
- By July 2009 Western Power was committed to reduce its SF6 emission by 40 kg (approximately 20%)

Environmental Concerns With SF6

- SF6 enhance Greenhouse Effect
- Most potent greenhouse gas known
- SF6 Global Warming Potential (GWP) is equal to 23,900 (i.e., the impact of 1kg of SF6 is equivalent to 23, 900 kg of CO2)
- Lifetime of SF6 in the atmosphere is 3,200 years



SF6 Major gas leak locations

- Flanges
- Gas Gauges and Filling Valves
- Gas Pipes





The Need for an Action
Current & Future Requirements

- Business goal and commitment

- Improve operational and maintenance efficiency of in service SF6 equipment

  - A simple top-up cost in average $3,000 (labor, equipment, switching,…) , Required outage duration of 4 hours to 3 days

  - A 19 years old CBs- Top up cost in the last 4 years $50,000 (33% of replacement cost),   No of call-outs 14

- Getting ready for future (a proactive approach)

  IEC standard (IEC 6227-1-1-2004) : Maximum 0.5 percent/year

  NEMA guidelines: Maximum 0.1 percent/year

  Prevent future exposure to environmental fines and penalties

Where to Start, What to Do & How to Do it?

Progress so far…

What has been done so far

- Developing a plan for structured training of maintenance crew
- Availability of maintenance parts are investigated and improved
- Budget is allocated for preventative maintenance of some SF6 equipment
- A leak management plan is developed to facilitate repair or replacement process
- A leak register database is developed
- Modified equipment specification for the new tender documents
- Life cycle cost analysis is conducted in identifying new preferred manufacturer

Outcome: Meeting business target

What to be done

- Optimum warranty requirement for SF6 equipment is under-review
- A QC process will be implemented to check quality of work at installation stage
- New measures are developed to measure response time in case of SF6 leaks
- Review of lesson learnt
- …

Case Study 2 Power Transformers Early Life Inspection (prior to O&M stage)

- Power transformers are large transformers
- allow voltages to step-up and step-down.
- The Most expensive and the most critical asset in Transmission network
- The unit replacement cost of transformers varies significantly, depending on the ratings. A 330 kV, 550 MVA transformer costs about $7 million, whereas a 66 kV, 1.5 MVA transformer costs about $100,000.

Case Study 2 …

Problem Statement:

Increased number of power TX early life defects including:

- Oil leaks due to poor sealing
- Corrosion due to moisture ingress
- Over-heating due to oil valves left closed
- Noisy tap-changer due to poor installation
- Damage to TX bushing due to poor/incorrect connection

Main Cause:

Degraded quality of QA and QC system due to:

- Moving from relying on a robust internal QA and QC assessment to relying on suppliers' QA and QC system
- Suppliers' QA and QC systems are degraded due to mainly financial pressures or market pressure

Case Study 2 …

Solution:

Introduction of the new inspection regime:

- **"Initial inspection" -** immediately post site assembly – To assist in identifying initial design and Installation issues on site and to assist with formalising contractual handover from the manufacturer / assembler to western Power.

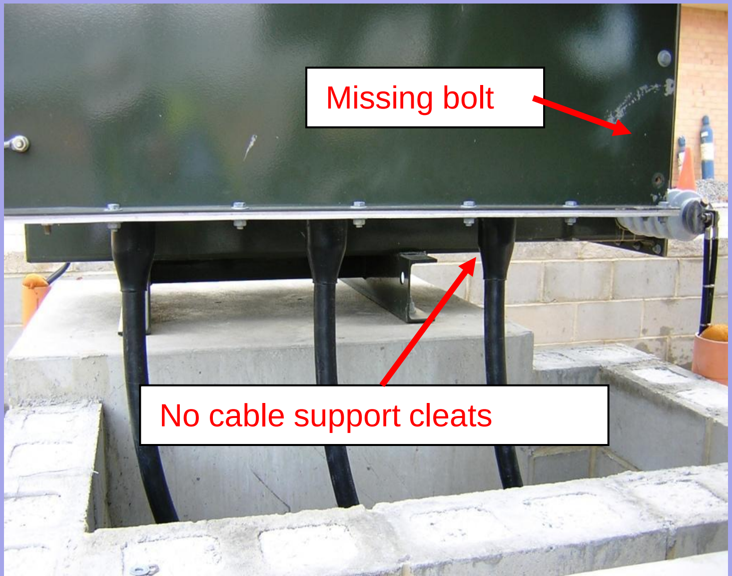
- **"Final inspection"** performed a week or two prior to energisation onto the system and after any electrical testing has been completed (so the primary connections do not need to be disturbed again) – To identify outstanding assembly, design or operational issues and ensure safe entry to the network.

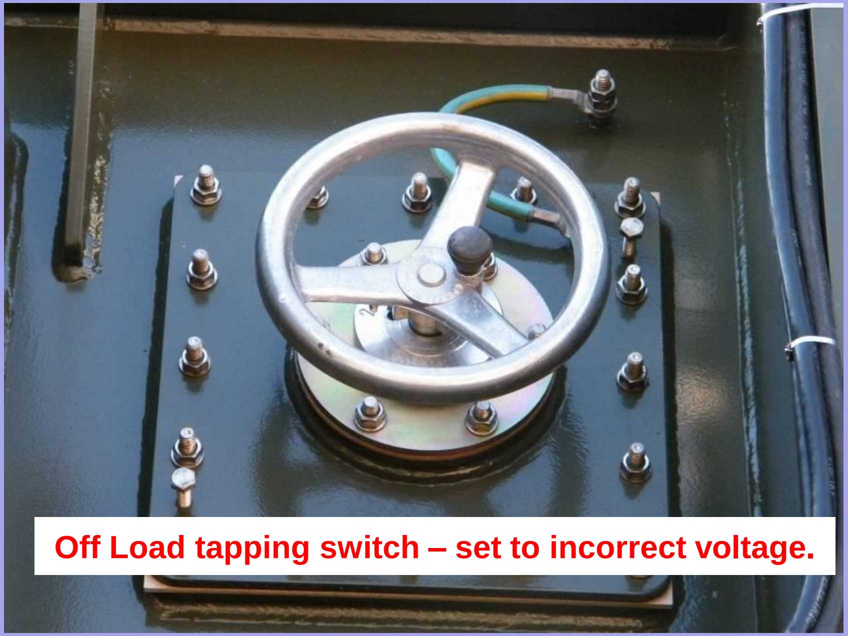
Case Study 2 …

Inspection Checklist:

The checklist is developed based on transformer Failure Modes per TX component including:

- Tap-changer
- Winding
- Tank and Oil
- Bushing
- Accessories
- Core





Case Study 2 …

Financial Benefits:

- *Internal Cost associated with the inspection: Approximately $4000 per TX*
- *Opportunity saving (prevented repair cost)to the business for any problem fixed: from $5000 to more than $23,000*
- *All the problems identified are fixed under warranty, therefore no repair cost to the business.*

Other Benefits:

- *Educating manufacturers and site assembly groups*
- *Improved technical specification for new tendering process*
- *Project Managers*
- *Construction Managers*
- *Commissioning Officers*
- *Services Groups*
- *System Operations groups*
- *Western Power Customers*

Conclusion

- *Pressures from stakeholders & market requirements have raised awareness of organisations in responsible management of their systems (assets or equipment) and the importance of their reliability*
- *Organizations need to have an understanding of their current and future position (Voice of Business, Voice of Stakeholders, Voice of Equipment AND Process)*
- *Stay focus on the business objectives, requirements and constraints*

Thank you for your attention!

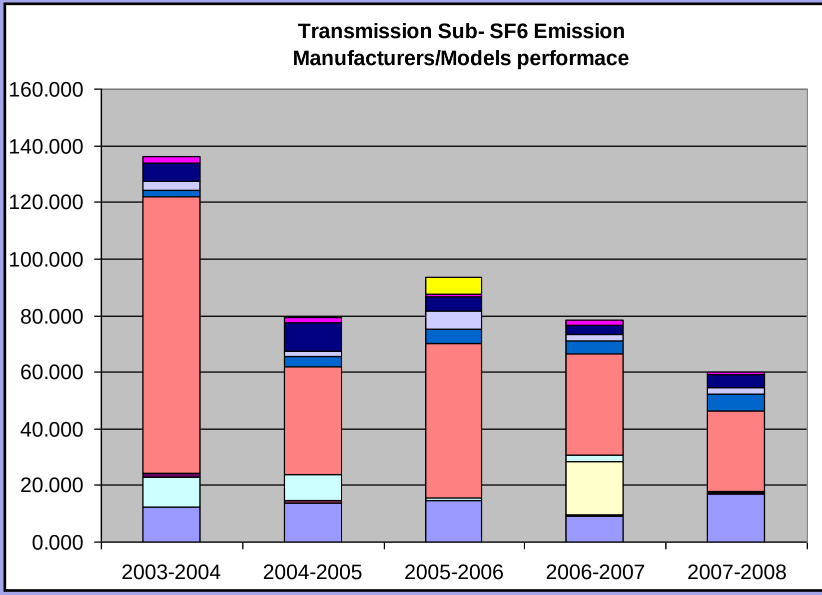
Reference:

Belanchard B,Verma D, “Maintainability – A key to serviceability and maintenance management”, John Wiley & Sons, 1955.

Current & Future Position

Identify where we are, and where we want to be with regard to SF6 emission reduction and ownership of SF6 Equipment

- **Voice of Business:** Understanding business goals, target and commitment (40 kg reduction)
- **Voice of Equipment** - Investigating SF6 CBs population and historical performance
- **Voice of Stakeholders** - Constraints and challenges, e.g. Outage, Obsolete CBs, Spare Parts, Maintenance Training and Skills, Budget, Specifications, Process and procedures, etc.
- **Voice of Process**: Existing process and policies



•Existing CBs usually show significant leak problems about 20 years
• In 2007, 50% of CBs aged 21 –25 years experienced gas leaks
• Asset replacement profile

Investigating the gap *

Six major areas:

1. Operation and Maintenance (O&M)
2. Data Management - Equipment performance monitoring and reporting with regard to SF6 emission
3. Procurement and Supply Chain (technical specifications)
4. SF6 Handling, Storage and Disposal
5. Training (promoting awareness, technical skills, …)
6. Preventative approach (Prior to hand over to O&M)

Closing the gap *

1. Analyzing opportunities and initiating improvement projects

2. Commitment from stakeholders:
- Improving individual Department performance
- Streamlining Departmental Functions based on equipment life cycle

3. Reviewing process and procedures to streamline departmental functions

4. Promoting awareness and providing training

5. Performance monitoring and providing feedback, which in turn influences the goals, policies and available budget

Support Slides

If Required

Reliability growth

- New system or products often display a lower reliability during the early development phases. System reliability can be improved by analysing and fixing some of the failure modes experienced. This concept is referred to as Reliability growth and was formally analysed for the first time in mid 1960s by James Duane, in the aircraft industry.

- A given reliability growth curve can be used to assess the test and evaluation time required to assess a target system reliability.

SF6 from electrical equipment in the atmosphere represents only 0.01 % of the man-made Global Warming

SF6 leakages from electrical equipment, annually represents only 0.1 % of the man-made Global Warming increase

Based on state of the art Technology & proper handling SF6 leakages from electrical can be reduced tremendously

SF6 Switchgear technology helps Energy Efficiency

- **SF6 gas insulated primary assets pose the greatest challenge in the foreseeable future in relation to safe handling, testing and recovery, from equipment in service. There are mandatory requirements in the EU for workers in this field to be accredited - and courses offering this training and accreditation are now available.**
- By attending this training we will have the opportunity to develop our processes and procedures in line with industry best practice – As surely similar mandatory accreditation for workers in Australia will be required in the near future - We can ensure we are already operating at the required standard – using the accepted methods – thus avoiding any quantum step change in methodology at short notice – whilst ensuring our environmental and safety compliance ahead of time.

- There are several pieces of legislation that require companies to either only 'pollute' to prescribed limits (eg approval conditions of a power station) or making pollution an offence, however there are only a few regulations requiring the reduction of pollution / greenhouse emissions. Some of the main examples include:

- 'Improvement'
- **Renewable Energy (Electricity) Act 2000** - requires retailers and wholesale purchases or electricity to purchase renewable energy, growing to 20% in 2020.
- **Energy Efficiency Opportunities Act 2006** - for large energy consumers
- **Carbon Pollution Reduction Scheme (not passed)** - allows nationwide cap on carbon
- **National Greenhouse and Energy Reporting Act 2007** - requires reporting only - not reduction in greenhouse gases

- Pollution
- **Environmental Protection Act 2086** (includes regulation controlling emissions, spills, approvals of new industry etc)
- **Contaminated Sites Act 2003**

- Additionally, there are Australian Standards or codes of practice that set minimum requirements with the most relevant being the ENAs industry guideline for SF6 management and AS2791.

Why Eclectic Utilities use SF6 equipment

Mainly due to SF6 electrical properties:

- SF6 dielectric strength is 2.5 times higher than air
- SF6 ability to break the arcing is 10 times higher than air, and
- SF6 ability to transfer the heating is 2 times higher than air.

What is the concern then? SF6 Leaks

where e is the natural logarithm base, t is the time interval of interest, and θ is the mean life. Mean life (θ) refers to the average lifetimes of all items under consideration and is equal to mean time between failure (MTBF) for the exponential time density function. The reciprocal of MTBF expresses the instantaneous failure rate λ. Therefore, the reliability function with an exponential time density can also be expressed as

$$R(t) = e^{-t/\mathrm{MTBF}} = e^{-\lambda t} \tag{4.3}$$

Assuming an exponential density function for the time variable best represents a scenario where the failure rate is essentially constant over the useful system operating life. This is frequently assumed during the course of reliability analyses and predictions. While variable failure rates are experienced during the infant mortality and wearout periods of a system life cycle, the constant failure rate assumption often works well after the system attains a steady state of operation. The flat portion of the familiar bathtub curve, illustrated in Figure 4.1 and often used to describe system reliability characteristics over the life cycle, represent this steady operational state.