Asset Health Indices for HV Assets and Probability of Failure

Electricity 2018, Eilat

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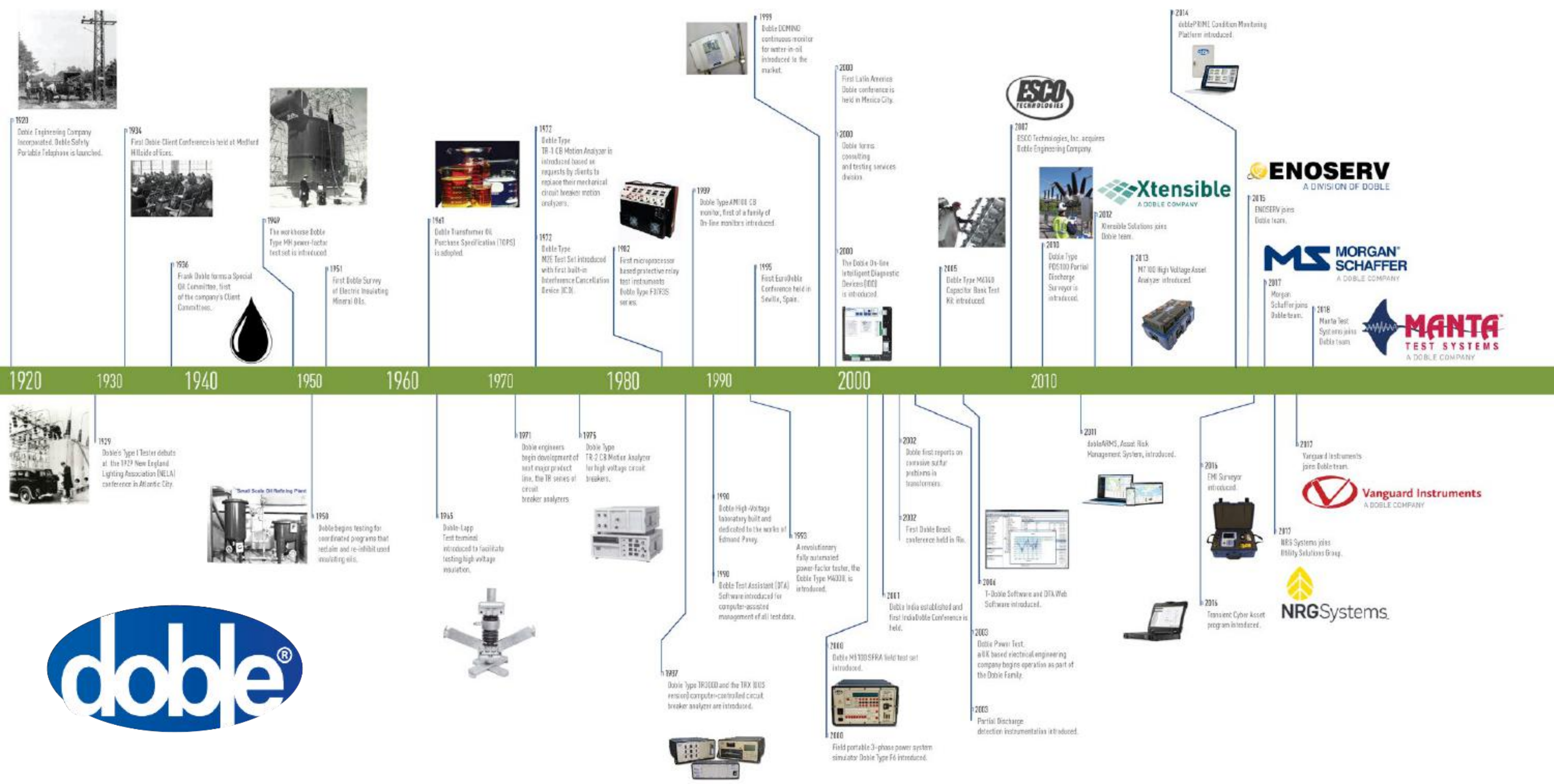

1920
Doble Engineering Company Incorporated. Doble Safety Portable Telephone is launched.
1929
Doble's Type I Tester debuts at the 1929 New England Lighting Association (NELA) conference in Atlantic City.
1934
First Doble Client Conference is held at Medford Hillside offices.
1936
Frank Doble forms a Special Oil Committee, first of the company's Client Committees.
1949
The workhorse Doble Type MH power-factor test set is introduced.
"Small Scale Oil Refining Plant"
1950
Doble begins testing for coordinated programs that reclaim and re-inhibit used insulating oils.
1951
First Doble Survey of Electric Insulating Mineral Oils.
1961
Doble Transformer Oil Purchase Specification (TOPS) is adopted.
1965
Doble-Lapp Test terminal introduced to facilitate testing high voltage insulation.
1971
Doble engineers begin development of next major product line, the TR series of circuit breaker analyzers
1972
Doble Type TR-1 CB Motion Analyzer is introduced based on requests by clients to replace their mechanical circuit breaker motion analyzers.
1972
Doble Type M2E Test Set introduced with first built-in Interference Cancellation Device (ICD).
1975
Doble Type TR-2 CB Motion Analyzer for high voltage circuit breakers.
1982
First microprocessor based protective relay test instruments Doble Type F3/F3S series.
1987
Doble Type TR3000 and the TRX (DOS version) computer-controlled circuit breaker analyzer are introduced.
1989
Doble Type AM100 CB monitor, first of a family of On-line monitors introduced.
1990
Doble High-Voltage laboratory built and dedicated to the works of Edmund Povey.
1990
Doble Test Assistant (DTA) Software introduced for computer-assisted management of all test data.
1993
A revolutionary fully automated power-factor tester, the Doble Type M4000, is introduced.
1995
First EuroDoble Conference held in Seville, Spain.
1999
Doble DOMINO continuous monitor for water-in-oil introduced to the market.
2000
First Latin America Doble conference is held in Mexico City.
2000
Doble forms consulting and testing services division.
2000
The Doble On-line Intelligent Diagnostic Devices (IDD) is introduced.
2000
Doble M5100 SFRA field test set introduced.
2000
Field portable 3-phase power system simulator Doble Type F6 introduced.
2001
Doble India established and first IndiaDoble Conference is held.
2002
Doble first reports on corrosive sulfur problems in transformers.
2002
First Doble Brazil conference held in Rio.
2003
Doble Power Test, a UK based electrical engineering company begins operation as part of the Doble Family.
2003
Partial Discharge detection instrumentation introduced.
2005
Doble Type M6160 Capacitor Bank Test Kit introduced.
2006
T-Doble Software and DTA Web Software introduced.
2007
ESCO Technologies, Inc. acquires Doble Engineering Company.
ESCO TECHNOLOGIES
2010
Doble Type PDS100 Partial Discharge Surveyor is introduced.
2011
dobleARMS, Asset Risk Management System, introduced.
2012
Xtensible Solutions joins Doble team.
Xtensible
A DOBLE COMPANY
2013
M7100 High Voltage Asset Analyzer introduced.
2014
doblePRIME Condition Monitoring Platform introduced.
2015
ENOSERV joins Doble team.
ENOSERV
A DIVISION OF DOBLE
2016
EMI Surveyor introduced.
2016
Transient Cyber Asset program introduced.
2017
Morgan Schaffer joins Doble team.
MORGAN SCHAFFER
A DOBLE COMPANY
2017
Vanguard Instruments joins Doble team.
Vanguard Instruments
A DOBLE COMPANY
2017
NRG Systems joins Utility Solutions Group.
NRGSystems
2018
Manta Test Systems joins Doble team.
MANTA
TEST SYSTEMS
A DOBLE COMPANY
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
doble

Overview

- Introduction: Asset Health Indices
- Data:
  - Understanding Failure modes and Correct tools for the job.
  - Condition Assessment and Monitoring feeds AHI process
- AHI Coding: encapsulate knowledge for your application
- Probability of Failure (PoF): where did that come from?
- Discussion/Conclusions

Asset Health Indices

- AHI is an estimate of an unknown variable: the actual transformer health
  - More data, will maybe give a better estimate
  - Estimating what – healthy enough to do what, exactly?
  - There is not one type of AHI
  - The AHI is a number at that time of analysis and only an estimate.
- Action, timescale, justification, auditable
- Choose a range or scale or labels which are convenient and not misleading
- Statistics are for guidance…not set in stone
- Machine learning can yield a gem in a whole lot of sand/silt/stuff… But someone has to be able to tell them apart

What problem are you trying to solve with AHI?

The actual asset health is an <u>unknown</u> value: the AHI is an *estimate*, a '*model*'

"all models are 'wrong', some models are useful", G. Box, Statistician

An index should have associated <u>action</u> & <u>timescale</u> related to the problem to be solved

More data, should enable a better estimate, a better AHI?

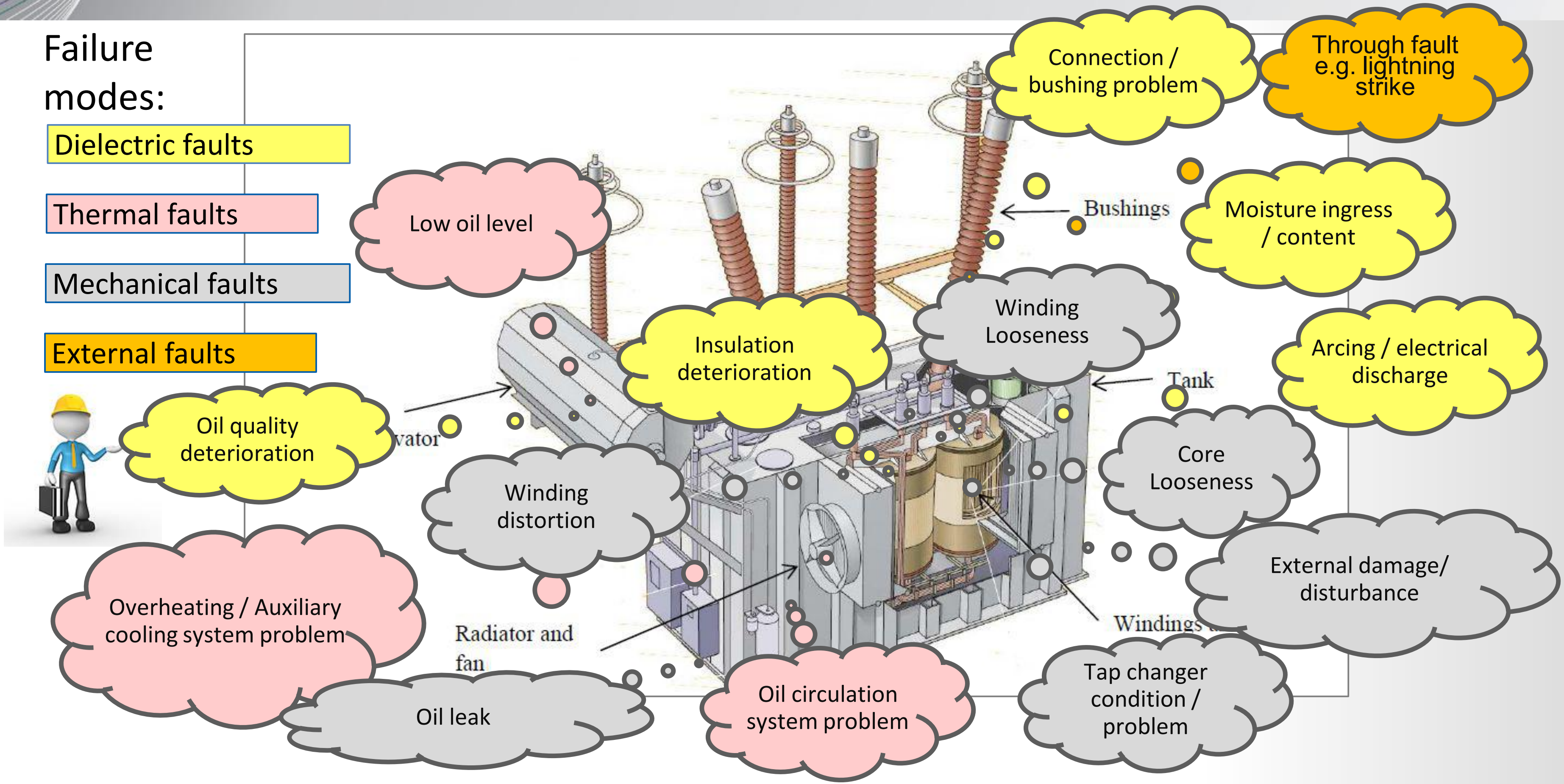
Whatever index we derive… it should not be a surprise!

How do you know you have succeeded?

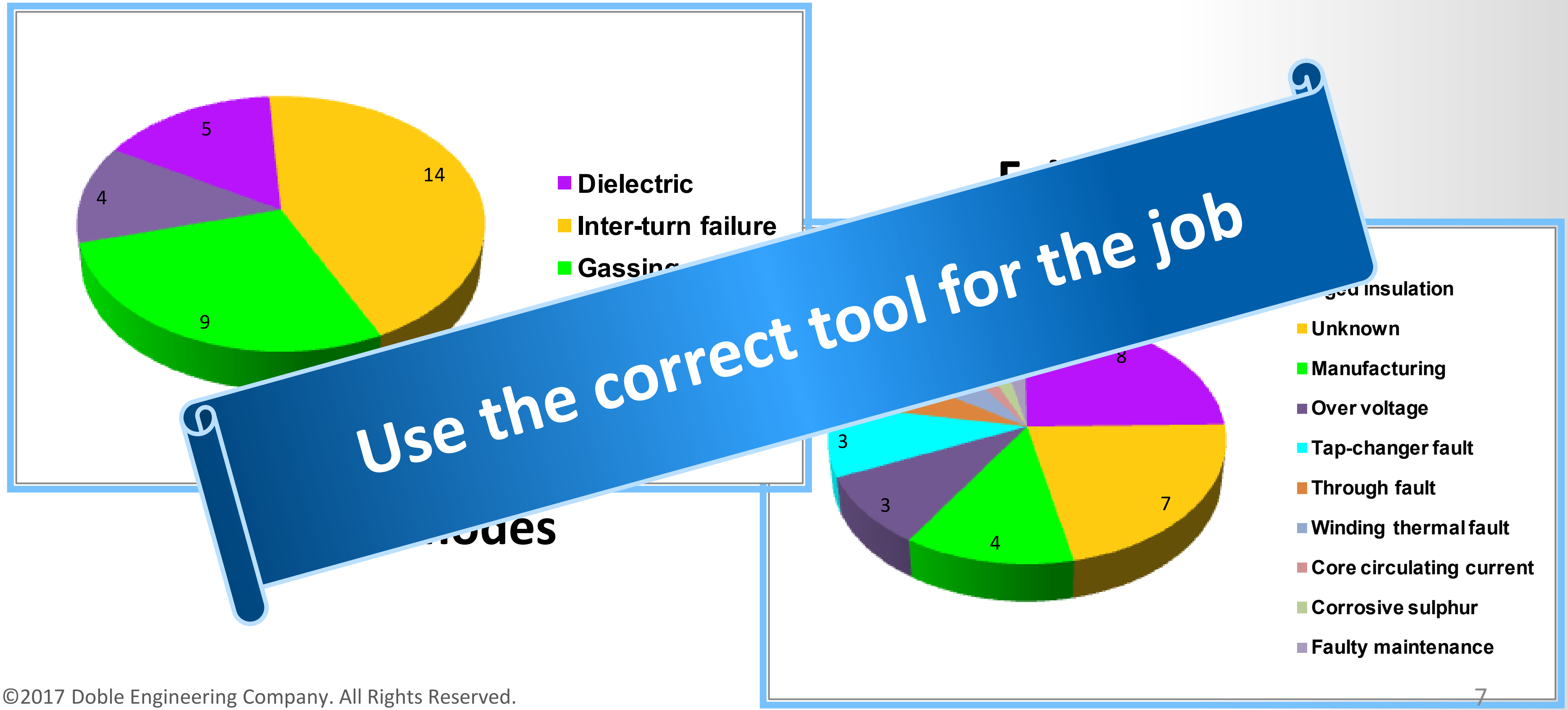
ISO 18095: Transformer Failure Modes

Failure modes:

- Dielectric faults
- Thermal faults
- Mechanical faults
- External faults



Understanding failures (real events)



Transformer condition monitoring/assessment feeds AHI score...

Install sensors that allow online periodic or permanent monitoring of critical assets.

Start with a survey to check and get an overview of the condition of the asset.

Do offline testing to verify and confirm the condition of critical asset found by survey or inspection.

Starting with the end point in mind

- The 3 C's of condition monitoring:
  - *Control* The measurement and the response
  - *Context* What are the operating constraints, ambient, load, OLTC…
  - *Conclusions* Actionable decisions. Justifiable, auditable, useful real actions
- Learn and iterate
- Data to support decisions
- Must have an action plan in place if an alarm goes off!
  - And/or decide we don't need to do anything

"Condition monitoring is more than just a box with lights on"

National Grid

AHI Coding - Index and Indices

- What scale should we use?
  - Linear, logarithmic, dynamic, weighted….

- If we use 1 – 10, say: 1 is new/good and 10 is ‘about to fail’:
  - what does 6 mean?
  - how does 6 compare to 7
  - is 6 twice as bad as 3? Twice as likely to fail?
  - How accurate or precise is the number?
  - What does 3.9 mean? And what if it changes to 4.2????

This needs to be thought about!

- Can we relate the health index to a ‘likelihood of failure’? “A real event”.

- Key to extracting value: **action** and **timescale**
- Key to keeping your job: justifiable audit trail

AHI Code definitions

If we use 1 – 10, say: 1 is new/good and 10 is ‘about to fail’:

what does 6 mean? How soon do we need to act?

Monotonic? Easy at the individual parameter level, harder with multiple

Status	Dissolved key gas concentration limits [µL/L (ppm)[a]]							
	Hydrogen (H_2)	Methane (CH_4)	Acetylene (C_2H_2)	Ethylene (C	Ethane	Carbon monoxide	Carbon dioxide	TDCG[b]
Condition 1	100	120	1					
Condition 2	101–700	121–400	2–9	51				
Condition 3	701–1800	401–1000	10–35	101				
Condition 4	>1800	>1000	>35	>				

Code	Description
1	No known problems
3	Slightly unusual dissolved gas signature
10	Possible arcing/sparking or partial discharge fault
30	Severe arcing/sparking or partial discharge fault
100	Very severe arcing/sparking or partial discharge fault, transformer at high risk of failure

Code	
A	transformer is expected
B	transformer is expected
C	transformer is expected
D	transformer is on active list for replacement within 2 years

Case Study – Logarithmic Scoring
The Outcome

League table for transmission operator – sorted by worst overall condition score

Current and Mitigated Condition | **Possible improvement in score** | **Component score based on sub-components**

Design/Manufacturer

								Overall Condition			Core and Windings			Oil		OLTC	Exterior
T-N		Ratio	Rated P	Manufact	Design	sign	Year	Now	Mitigated	Possible Ir	Dielectric	Thermal	Mechanic	Ageing	Contaminat		
T	1	400/132 kV	240 MVA	AEI Wythen	A04a	32	1965	221	213	8	100	100	1	13	10	3	10
T	2	275/132 kV	120 MVA	EEC	E11b	32	1959	170	103	68	30	60	1	190	10	10	10
T	3	400/275 kV	1000 MVA	GEC	G02b	104	1994	170	135	35	30	60		36	100		1
T	4	275/132 kV	120 MVA	EEC	E11b	32	1959	154	143	11	30	100	1	23	10	10	3
T	5	275/66 kV	180 MVA	CP	D07	12	1965	152	126	26	60	60	1	70	10	1	
T	6	275/132 kV	120 MVA	MVE	M01	5	1957	151	94	57	30	60	1	160	10	3	10
T	7	400/275 kV	750 MVA	HHE	H02	111	1971	147	100	47	3	60		140			3
T	8	275/33 kV	100 MVA	PPT	P21	104	1972	144	139	5	1	3	100	13		1	10
T	9	400/132 kV	240 MVA	CAP	C04	32	1968	138	85	54	10	60	1	140	30	1	
T	10	275/132 kV	240 MVA	HHE	H07a	12	1964	133	107	26	1	100	1	70	10	3	
T	11	400/132 kV	240 MVA	AEI Wythen	A04b	102	1967	132	106	26	10	60	1	70	10	3	
T	12	400/132 kV	220 MVA	PPT	P06a	131	1967	131	107	24	1	60	1	63	10	1	10
T	13	275/132 kV	240 MVA	HHE	H07a	12	1964	129	106	23	1	100		63	10	1	
T	14	275/132 kV	120 MVA	EEC	E11a	102	1955	129	105	24	10	60	1	70		1	10
T	15	275/132 kV	240 MVA	HHE	H07a	12	1966	129	106	23	1	100		63	10	1	
T	16	275/132 kV	120 MVA	EEC	E11b	32	1959	129	107	22	30	60	3	43	30	10	
T	17	275/132 kV	120 MVA	FER	F08	120	1956	124	105	19	3	60	1	50	10	1	
T	18	275/132 kV	180 MVA	FUL	L05	111	1962	122	99	23	1	60		63	10	1	
T	19	400/132 kV	240 MVA	AEI Wythen	A04b	102	1967	122	96	26	1	60		70	10	3	
T	20	275/66 kV	120 MVA	AEI Rugby	A10	3	1960	122	106	16	100	3	1	40	10	1	

How does AHI relate to Probability of Failure

What is the probability of failure of an asset?

100%

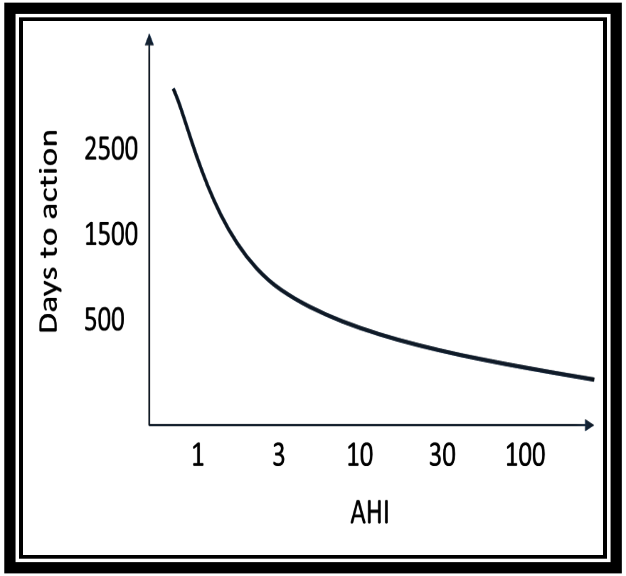
Economist: J. M. Keynes:
“ ***In the long run*** **we are all dead.**”

Singer/Songwriter: Paul Simon
“**Everything put together, sooner or later, falls apart.”**

So… we need to have some interest in time: probability of failure, by when?

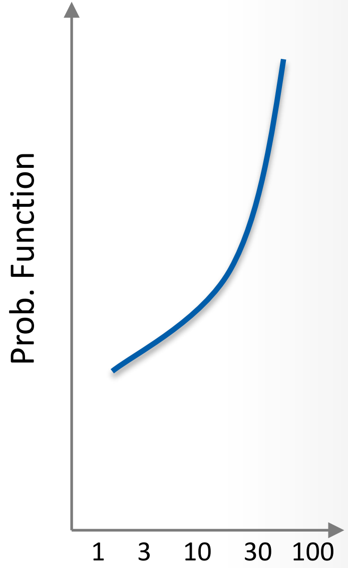
Timescales must be included?

How do we move from data to AHI to PoF?



Log	More likely to fail
1	X
3	3X
10	10X
30	30X
100	100X

Coding – AHI
Given timescale



Timescales and condition (AHI)

PoF increase with higher AHI score

Tabulating PoF

Justifying category labels and PoF… assigned a replacement category

Category	AHI Range	Description	First estimate of Notional PoF per year
A	0 - 30	Considered under normal operation	0.05% PoF
B	31- 50	Expect to replace within 15 years	0.2% PoF
C	51- 70	Expect to replace within 10 years	0.4% PoF
D	71 – 90	Expect to replace within 5 years	0.8% PoF
E	**91 - 100**	**On replacement list for within 2 years**	**1.5% PoF**

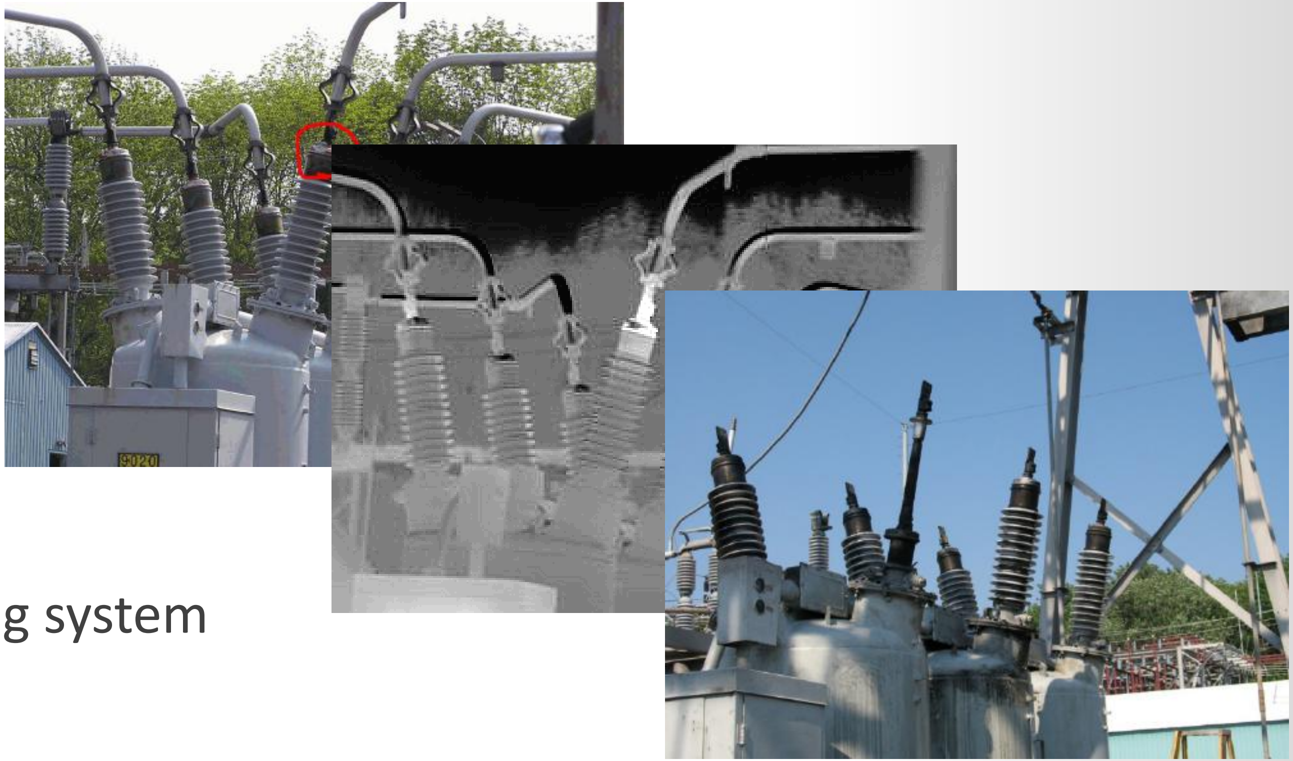
Or you could just choose:

- Label each unit with a category
- Timescale for action
- With PoF? Based on 'historic data'?
- Not necessarily linear, or consistent
    - but might be good enough for your system as a starting point

Category	Timescale	PoF estimate
5	1 month	12%
4	1 year	4%
3	2 years	2%
2	5 years	1.5%
1	15 years	1%

Case Study - When available data changes…

- PoF was x%
- Known failure mode
- Action…was
- But failed!



- Iterate the AHI scoring system

Summary

- **AHI is an estimate of a generally <u>unknown</u> variable**: actual transformer health
  - More data, should be a better estimate?
- **The index should be useful:**
  - Choose a range or scale or labels which are helpful, not misleading
- **Correct tools should be used to determine that AHI**
- **An index should be calibrated and have associated <u>action</u> & <u>timescale</u>**
  - Timescales should calibrate – be consistent across failure modes and assessments
- **PoF may be difficult to justify if working from raw data**
  - **Hence why AHI scoring can help provide more accurate numbers**
- **PoF based on historic values may be justifiable as a starting point.**
  - **But system always needs developing…its not a one off exercise.**


THANK YOU