

Creating and Using Meaningful Asset Health Indices (AHI)

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AltaNova Introduction

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Altanova History



I.S.A. Istrumentazioni Sistemi Automatici S.r.l. is established in Taino ITALY

1999 TECHIMP was born as a spin-off from the University of Bologna ITALY.

- 1.S.A. and TECHIMP merge giving birth to the ALTANOVA GROUP
- 2019 INTELLISAW joins ALTANOVA GROUP

2021

1938

ALTANOVA GROUP becomes part of ESCO Technology Group and joins the Doble Engineering Company, as part of the USG division.





Altanova Today













5550+ CUSTOMERS GLOBALLY



Part of ESCO Technologies' Utility Solutions Group

PRODUCT BRANDS



Our Solutions

Electrical Test Equipment

Essential for day-to-day maintenance tests of electrical assets. Useful in specific phases of the asset lifecycle:

- Procure
- Operate
- Maintain
- Decommission.

Professional Services

Diversified offer according to the electrical asset lifecycle:

- Installation and commissioning
- Diagnostic test
- Data analysis
- Consultancy
- Training.





Monitoring Systems

Shift from a time-based maintenance to a condition-based maintenance.

Focus on predictive maintenance and shift in focus from electric asset value cost to network outage costs.

Strong evolution of digitalization trend in the power industry.



Power transformers Current & voltage transformers **Circuit breakers** Protective relays HV gas insulated switchgears Meters and transducers MV/HV/EHV cables Rotating machines MV/LV switchgears Variable speed drives **Overhead** lines Batteries



Testing And Monitoring Solutions For:





Creating and using meaningful Asset Health Indices (AHIs)

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Agenda

Presenter Background

<u>A little on transformers</u>

Some aspects of Asset Health Indices

- Failure modes, expectations and health indexing
- Models, and their limitations
- What does an AHI mean?
- Dunning-Kruger
- Risk of Using Risk Matrices
- Tooth Fairy Science
- Anscombe

Conclusion/Discussion

Aim:

Provide you with something of interest/value/use in your 'day job'.



Presenter background

- National Grid UK: substation tech specialist, transformers
 - Go/NoGo decisions: timescales & actions
- National Grid US: Substation Asset Mgr.
 - >2,000 power transformers, many >80 years old...
- Doble Engineering
 - Asset Management and Monitoring Technology







ΛLTΛΝΟVΛ

isa> MS MORGAN WPHENIX TECHMP

Asset Management Context

- ISO 55000: Asset management
- Talk technical to financial people... financial to technical people
 - 'Translation' needed AHIs sometimes used as a substitute
- Risk Cost Performance Sustainability
- Risk is a combination of hazard probability and consequence
- Expectations actions feedback
- Plan do check act
- Smart analytics: 95% can be achieved through cleaning up the data and use of standard statistical tools...
- Make data available...

"Plans are of little importance, but planning is essential." — Winston Churchill





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Transformer Assets:





Big Money, Big Data... ...big responsibilities!



Failure modes are not always obvious





The unexpected...





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Expectations: failure modes¹



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1: ISO 18095 "Condition Monitoring and Diagnostics of Power Transformers"

Expected Life?



What is the **probability of failure** of an asset?

100%

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?



Probability of Failure: when???



Story of the tires... if they fail, you may need a new car...

Pressure is at 35 psi for front left tire: what's the PoF of the car?

PoF this week? PoF this month? Today?

More data?

It's Tuesday (+/-15%, you may need to check...) Ok... you're doing 100 kph (62.5mph)







And the pressure is now 22 psi...



Too late. Result?

Misery...

No tacos...

Asset Health Index



A number/code/color/term to represent the health of an asset: it is our 'best estimate' of the asset health: it is a *model*

Whatever index we derive...

... it should not be a surprise!

It should 'document' what we think we know!

It *may* be a proxy for 'Probability of Failure'



Physicist Richard Feynman



On physics:

"...you have to have an understanding of the connection of the words with the real world."

These blocks are not transformers...



These health indices are not transformers...



They are *representations* of transformers... they are *'models'* ... digital twins!

"All models are wrong, some models are useful" C.J. Box



More thoughts from inside a Box¹



"Since all models are wrong... you cannot obtain a "correct" one by excessive elaboration."

"Since all models are wrong... you must be alert to what is *importantly wrong*. It is inappropriate to be concerned about mice when there are tigers abroad."

"The only question of interest is: 'Is the model illuminating and useful?"

And from Dr. Cox²:

"The idea that complex physical, biological or sociological systems can be exactly described by a few formulae is **patently absurd.**"



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What does a health index mean?

Depending on how you built the 'health index', it could:

- Summarize what we already know
- Indicate likely failure modes and timescales for action
- Help rank assets for intervention based on 'urgency'
- Have poor precision/accuracy
- Miss 'serious issues' if we do not test for them

A 'health index' CAN NOT tell you that the asset will NOT fail in a given time period!

Key words: Calibrated, Monotonic Auditable, Justifiable "Life is under no obligation to give us what we expect"

Irrfan Khan, Actor



	#	н	Uploading Date	Testing Date	Asset Type
> ali	U3	91.2 %	11/10/2021	21/01/2014	POWER
> eDİ	U1	63 %	11/10/2021	31/05/2010	POWER
> etil	U1	64.4 %	11/10/2021	13/01/2011	POWER
> alil	U1	69.1%	11/10/2021	12/07/2012	POWER
> atl	U1	62.4 %	11/10/2021	26/11/2013	POWER
> etil	U1	56.8 %	11/10/2021	21/01/2014	POWER
> atil	U2	13.2 %	11/10/2021	31/05/2010	POWER
> 000	U2	23.7 %	11/10/2021	13/01/2011	POWER
> :0]	U2	27.6 %	11/10/2021	12/07/2012	POWER

Key Words

• Calibrated:

All identical indices have **identical timescales** for action

(all '3s' need to be checked in 1 month, say)

Auditable

We can track the index back to data, failure modes and timescales (we have the evidence and the analysis)



• Monotonic:

A 'worse' index is always associated with a **more urgent** condition (all '3s' are worse than all 2's, say)

• Justifiable:

The process of generating an index is based on **failure mode analysis/urgency**

(the analysis makes sense)

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What if we just had one or two assets?

- Gather data
- Read the manuals/guides
- Test and assess
- Make a plan to intervene:
 - maintain, replace, refurbish...
- Act on the plan in a timely manner
- Repeat

- Who needs a health index?
- A health index... what would it do for our one or two assets?



Raw data to an index



Start with something 'simple' – tire pressure in psi. If the tire pressure drops too much, the tire may fail, possibly taking the car with it.

The more the pressure drops, the more urgent the situation is!

How much of a drop is too much? Where are you on the failure mode curve?

How do we turn the measured pressure into a health index?

- Choose your parameter(s)
- Identify symptoms and failure modes
- Expected timescales? Driver, route, conditions, maintenance?
- Where are we on the failure mode curve?
- How long do we have?



Creating an Index

What question are you trying to answer?

For just one asset:

- what data do you need, what analysis, what resources?
- Can you identify failure modes and timescales?
- What intervention is needed? When?

What do you want the index to 'look like': letters, numbers, other?

What categories are acceptable? Useful?

Code	Code	Code	Timescale For Action
А	1	John	'Regular' activity
В	2	Paul	5 - 15 years

George

Ringo

Bert

Advantage of **NOT** using numbers: You will not do **BAD** math and start calculating

'risk' values

С

D

Ε

3

4

5



2 - 5 years

0.5 - 2 years

<6 months

Linear weighted scoring



Evaluate components... choose a scoring system: say **1=good** through **5=bad**

Factor	Trf 1	Trf 2	Trf 3
DGA Main Tank Score	2	1	1
Dielectric Score	1	1	1
Thermal Score	2	1	1
Mechanical Score	3	4	1
Oil Score	1	1	1
DGA LTC Tank Score	3	1 🔇	5
Operational Score	2	3	3
Design/manufacturer Score	1	4	1
Subject Matter Expert Score	3	1	2
Sum	18	17	16

HOW DID WE GET THESE INDIVIDUAL SCORES??? Note: NO AGE SCORE !!!

If you were given this data today... ...which transformer would you investigate first? And why?

Trf 3 because this is the most urgent component

Timescales need to be **calibrated** so all 'X's are the same **timescale**: For example: If a Thermal '5' means do something in 3 months then a DGA '5' also means do something in 3 months...



MAX and ENUM



Calibrated scores: 1=good through 5=bad

Factor	Trf 1	Trf 2	Trf 3	
DGA Main Tank Score	2	1	1	
Dielectric Score	1	1	1	
Thermal Score	2	1	1	
Mechanical Score	3	4	1	
Oil Score	1	1	1	
DGA LTC Tank Score	3	1<	5	>
Operational Score	2	3	3	
Design/manufacturer Score	1	4	1	
Subject Matter Expert Score	3	1	2	
Sum	18	17	16	
Normalized Sum (%)	40.0	37.8	35.6	

Trf	5's	4's	3' s	2' s	1' s	
Trf 1	0	0	3	3	3	
Trf 2	0	2	1	0	6	
Trf 3	1	0	1	1	6	

Trf 3 has a MAX of 5 and is highest priority – verall score.

What if there were two Trfs with a MAX of 5?

Use enumeration to count how many of each score: the ranking is then highest Enum first, lowest last

Enum	Rar
00333	
02106	
10116	

3

2

1

The ENUM system is easy to start small and grow – and retain urgency

Choose your modeling approach



dobleARMS Ho	ome > Assessments																		Susan (
Customer Settings	Sustomer Settings Asset Management Entity Management User Management Role Management Assessments Notifications Risk / Criticality Asset Lifecycle Configuration																		
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Mecha Operat	tional				IM	15				30	- Targeted					r		Maxin	numScore
Breaker					LTC			•		10	- Indicative		_		U	' 1		Aver	ageScore
 Battery Rotating I 	Machine				Mechan	cal		•		10	- Indicative				Λ	Anvin	num	Aver	ageScore
					Operatio	nal		•			3 - Loose					Ιαχιι	num	Aver	ageScore
Weigl	hted																		
Last Update A (UTC -05:00)	а <i>ні</i> Asset Type KV	Online Loss Of Life	Offline Loss Of Life	Aggregated Risk	Availability Risk	CustomerImp Risk	Environmenta Risk	Financial Risk	Reliability Risk	Safety	Risk Ann Reve	ual Replacer nue Cost	ment Replaceme t Time	nt					
<u>3 A</u> 04/01/2009 1	30 Three Windi 154	N/A	N/A	77	51	10	10	51	10	22	2 100000	2000	26 weeks	A					
07/12/2017 8	18 Three Windi 154	N/A	N/A	14	8	8	3	3	1	1	100000	2000	26 weeks	Ξ					
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				07/10/00170	20 71												400000	2000	~

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Key question







A little learning?



The Dunning Kruger effect



Kruger, Justin; Dunning, David (1999).

"Unskilled and Unaware of It"

Journal of Personality and Social Psychology. 77 (6): 1121–1134

"People with a little knowledge usually have overconfidence in their ability"



Get started and grow



System Overview: only 4 codes! (Categories)

Original System 1=bad, 4 = good

Code	Original System
1	transformer is on active list for replacement within 2-5 years
2	transformer is expected to last up to 5 years and may need to be replaced in 5-10 years
3	Plan to replace ahead of anticipated asset life, design issue identified
4	transformer is expected to last for the foreseeable future, and at least 15 years. No plan to replace.

Revised System – still 1-4, but more detail

Code	Original System
1	transformer is on active list for replacement within 2-5 years
2a	transformer is expected to last up to 5 years and may need to be replaced in 5-10 years, may well
	develop into a 1
2b	transformer is expected to last up to 5 years and may need to be replaced in 5-10 years due to
	insulation ageing.
3 a	Plan to replace ahead of anticipated asset life, design issue identified
3b	Plan to replace ahead of anticipated asset life, design issue identified but not serious.
4	transformer is expected to last for the foreseeable future, and at least 15 years. No plan to replace.



How about Log/Exp scales?



League table for transmission operator:

sorted by worst overall condition score

	Current and M			Mitigated Condition Possible			Component score based				
Design/Manufacturer		١		improv	vement	on	sub-compo	onents			
		1		in scor	e						
		1		/							
		\checkmark		K		K	-	> >			
			Overall Condition	on	Core	e and Windin	gs	Oil		OLTC E	xterior
T-N Ratio Rated P Manufact Desig	n 🗾 sign 🗾 Year	Now	🛃 Mitigated 🗾	Possible Ir	Dielectric	Thermal	Mechanic 🗾	Ageing 🔼 C	ontamina 🚬	-	_
T4315 400/132 kV 240 MVA AEI Wythen A04a	32 1965	221	213	8	100	100	1_	13	10	3	10
T3040 275/132 kV 120 MVA EEC E11b	<u>32</u> 1959	170	103	68	30	60	1	190	10	10	10
T6975 400/275 kV 1000 MVA GEC G02b	104 1994	170	135	35	30	60		36	100		1
T3039 275/132 kV 120 MVA EEC E11b	32 1959	154	143	11	30	100	1	23	10	10	3
T4259 275/66 kV 180 MVA CP D07	12 1965	152	126	26	60	60	1	70	10	1	
T2370 275/132 kV 120 MVA MVE M01	5 1957	151	94	57	30	60	1	160	10	3	10
T5961 400/275 kV 750 MVA HHE H02	111 1971	147	100	47	3	60		140			3
T6201 275/33 kV 100 MVA PPT P21	104 1972	144	139	5	1	3	100	13		1	10
T5566 400/132 kV 240 MVA CAP C04	<u>32</u> 1968	138	85	54	10	60	1	140	30	1	
T4409 275/132 kV 240 MVA HHE H07a	<u>12</u> 1964	133	107	26	1	100	1	70	10	3	
T5581 400/132 kV 240 MVA AEI Wythen A04b	102 1967	132	106	26	10	60	1	70	10	3	
T4686 400/132 kV 220 MVA PPT P06a	<mark>131</mark> 1967	131	107	24	1	60	1	63	10	1	10
T4406 275/132 kV 240 MVA HHE H07a	<mark>12</mark> 1964	129	106	23	1	100		63	10	1	
T2300 275/132 kV 120 MVA EEC E11a	102 1955	129	105	24	10	60	1	70		1	10
T4258 275/132 kV 240 MVA HHE H07a	<mark>12</mark> 1966	129	106	23	1	100		63	10	1	
T3041 275/132 kV 120 MVA EEC E11b	<u>32</u> 1959	129	107	22	30	60	3	43	30	10	
T2521 275/132 kV 120 MVA FER F08	120 1956	124	105	19	3	60	1	50	10	1	
T3583 275/132 kV 180 MVA FUL L05	111 1962	122	99	23	1	60		63	10	1	
T5434 400/132 kV 240 MVA AEI Wythen A04b	102 1967	122	96	26	1	60		70	10	3	
T3139 275/66 kV 120 MVA AEI Rugby A10	3 1960	122	106	16	100	3	1	40	10	1	

Categories Feedback Loop



	Ass	et Health C:	ategory					
Transformer	Before Scrappin <u>c</u>	After Sprapping	% Accur	ate		Reaso	nfor Scrapping	
1	27		50		As	set Health (Category	
2	28 28	2a	100	Transformer	B efor e Scrapping	After Scrapping	% Accurate	Reason for Scrapping
3	1	2a	50	8	1	2b	50	Overheating fault - thought un-repairable but it was!
				9	1	1	100	Failed Suddenly but RMHZ in place as suspected winding circulation currents, known design issues. Operated to failure.
4	2b 2a	2b 2a	100	10	2b	3	50	Suspected overheating issues and not in the windings. Overheating on shield rings (known design issues). But not as a ged as predicted.
6	2b	2b	100	11	2b	3	50	Suspected very aged insulation, poor design. Not as aged when scrapped. Even with > 3ppm 2-FAL.
7			100	12	2b	3	50	Suspected very aged insulation, poor design. Not as aged when scrapped.
	\checkmark	\bigcirc		13	4	2b	25	Failed Suddenly/Insulation Ageing. FFA level had been masked due to oil processing/regeneration
				14	2a	2a	50	Failed Suddenly/Selectorfault. But had suspected core frame insulation issues which were correct

"The Risk of Using Risk Matrices"



"Furthermore, Risk Matrices (RMs) are recommended in numerous international and national standards such as ISO, API, and NORSOK. The popularity of RMs has been attributed in part to their visual appeal, which is claimed to improve communications."

"Despite these claimed advantages, we are not aware of any published scientific studies demonstrating that RMs improve risk-management decisions. (The use of RMs to analyze and manage risks *may* be better than doing nothing.)"

- Range compression: same category for very different risks
- Centering bias: people avoid the extremes
- Category definition bias: people make stuff up
- Ranking reversal issues: changing scales can be bad
- Lie factor: misrepresentation (Stanford)
- "How to measure anything" Douglas Hubbard²...

Sapolski: 'We think in categories³'

1: "The Risk of Using Risk Matrices", Thomas, Bratvold & Bickel, Soc. Petroleum Engineers, Annual Tech Conf., New Orleans, USA, 2013 2: "The Failure of Risk Management – why it's broke and how to fix it", D. Hubbard, 2009

3: Stanford University, "Introduction to Human Behavioral Biology" https://www.youtube.com/watch?v=NNnIGh9g6fA



Using an Index



You've compressed a lot of data, rules, guides and detail into a single value. You have put groups/codes/categories in place: DOES IT HELP???

Problem of thinking in categories:

- Things within a category are seen as more similar than those in other categories
- Things in **other** categories are seen as **more different** than those in this category
- Why treat the members of a category in the same way???

Use a percent score? Percent of what? What does the number mean?

Is the index 'useful'??? Calibrated, Monotonic, Auditable, Justifiable?

What was the question again? What are you asking the AHI to do?



Perils of Summary Statistics



Anscombe Quartet¹: 4 data sets with similar statistical properties:



Anscombe Quartet: the visual properties, however, are quite different The implications are very different...

- 1: <u>https://en.wikipedia.org/wiki/Anscombe's_quartet</u>
- 2: http://www.thefunctionalart.com/2016/08/download-datasaurus-never-trust-summary.html
- 3: https://www.autodesk.com/research/publications/same-stats-different-graphs



Summary Statistics



Datasaurus Dozen

Х	Mean:	54.26
Υ	Mean:	47.83
Х	SD :	16.76
Y	SD :	26.93
Сс	orr. :	-0.06







https://www.autodesk.com/research/publications/same-stats-different-graphs

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Post hoc, ergo propter hoc: Placebos? PHENIX TECHMP

Present fleet status

Replace only oldest

New

weighted

2

1 1.6

1.6

3

2.8

1.4

2

3

1

2 1.4

1.6 1.4

1.4

3.2

1.6

2

1.2

1.8

1.85

Replace at random

	[L		New Age
I.D.	YoM	Age	DGA Score	indings Sco	Age Score	Weighted Sum	New Age	Score*
S1	1987	29	3	1	2	2	29	2
S2	1952	64	1	1	5	1.8	1	1
S3	2001	15	2	1	2	1.6	15	2
S4	1971	45	1	1	4	1.6	45	4
S5	1976	40	5	1	3	3	40	3
S6	1968	48	4	1	4	2.8	48	4
S7	1976	40	1	1	3	1.4	40	3
S8	1959	57	1	2	4	2	57	4
S9	1975	41	1	5	3	3	41	3
S10	2015	1	1	1	1	1	1	1
S11	1959	57	1	2	4	2	57	4
S12	1986	61	2	1	5	2.2	1	1
S13	1958	58	1	1	4	1.6	58	4
S14	1965	65	1	2	5	2.2	1	1
S15	2004	12	2	1	1	1.4	12	1
S16	1965	51	5	1	4	3.2	51	4
S17	1960	56	1	1	4	1.6	56	4
S18	1964	52	2	1	4	2	52	4
S19	1996	20	1	1	2	1.2	20	2
S20	1983	33	1	2	3	1.8	33	3
Average	Average	42.25	1.85	1.4	3.35	1.97	32.9	2.75
Weights	Age	20						1
	Windings			Expected life		60		
	DGA	40		Replace	number ~	3		

		New Age	New
Replace?	New Age	Score*	weighted
	29	2	2
	64	5	1.8
	15	2	1.6
	45	4	1.6
	40	3	3
*	1	1	2.2
	40	3	1.4
	57	4	2
	41	3	3
	1	1	1
	57	4	2
	61	5	2.2
*	1	1	1
*	1	1	1.4
	12	1	1.4
*	1	1	2.6
	56	4	1.6
	52	4	2
	20	2	1.2
	33	3	1.8
	31.35	2.7	1.84

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Tooth Fairy Science... Raton Perez¹?

Harriet Hall, MD²

You could measure how much money the Tooth Fairy leaves under the pillow, whether she leaves more cash for the first or last tooth, whether the payoff is greater if you leave the tooth in a plastic bag versus wrapped in tissue versus 'free', multiple teeth, tooth under pillow or by the pillow etc etc..."

"You can get all kinds of good data that is **reproducible** and **statistically significant**."

"Yes, you have learned something. **But you haven't learned what you think you've learned**, because, sadly, there is no real Tooth Fairy." (*So far as we know…*)

1: <u>https://skepticalinquirer.org/exclusive/tooth-fairy-science-part-1/</u> 2: "Memoirs of a Female Flight Surgeon", H. Hall







Condition Monitoring?

If a monitor gives an alert – use that 'by itself' to trigger the action plan you put in place when the monitor was installed.

- Tell me you have thought about the alert settings!
- Tell me you've a plan for every alert on every monitor?

Don't go from ignorance to negligence... an index won't save you!





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Thoughts?



Sapolsky: We think in categories (which is misleading) Risk Heat Maps are usually misleading (many reasons) Asset Health Indices may be misleading (4 adjectives)

Box: All models are wrong, some models are **useful Duning-Kruger**: A little learning is a **dangerous** thing





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Summary



Creation:

- Identify the question to be addressed
- Gather appropriate data
- Identify symptoms and failure modes
- Identify timescales
- Choose scoring system and codes calibrated and monotonic
- Don't over elaborate

Usage:

- Is the question addressed
- Sanity check feedback loop
- Understand the need to translate: technical to financial etc
- Is the message getting through





Thank you!

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Discussion



Thank you for attending this webinar:

- we hope you got something useful from it!

Questions? Comments? Feedback?

Please email and we will respond directly!

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