Reliability: A Compound Effect

by **Traci N. Hopkins**

What is your definition of reliability?

If you ask this question 100 different people, you will receive nearly 100 different answers.

However, the underlying theme will remain the same: Reliability is the expectation that the asset in question will perform as designed and as expected without fail.

However, at some point in the life of that asset, there will be a "blip" in its operation that will lead to two very definite outcomes.

The first is that this item will now be viewed as "unreliable".

The second is permanent failure.

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Traci Hopkins started her journey in electric power reliability in June 2012 with SDMyers, LLC in the Training & Education department. Shortly after, she transitioned into the role of Diagnostic Analytic Coordinator for the international market while continuing to support training & education through international events. In 2017 she made her way back to T&E as the Sr. Training & Education advisor and Adjunct Instructor. Recently, she has joined the Electric Power Reliability Alliance (EPRA) team as Membership Recruitment Coordinator. Traci has received the CRL, MTMP, MTRP and DPS Training certifications. Traci is also a member of IEEE PES, the Association of Asset Management Professionals, and WIRAM (Women in Reliability and Asset Management) organizations.

What is the definition of reliability and how do you maintain an asset's reliability? Your answer should funnel down to three distinct areas: small changes, consistency, and time.

Now that we've defined Reliability, let me ask the question: How do you maintain your asset's reliability? Similar to the first question, if you ask 100 people, you will receive a multitude of strategies and actions to ensure an asset's reliable status. However, the key to maintaining reliability can be written as a simple equation:

Small Changes + Consistency + Time = Reliability

This "Reliability Equation" is nothing more than the "Compound Effect". Let us break down this equation, evaluate each variable and observe how they apply to electric power reliability, specifically transformer reliability.

Small Changes

In our current culture we want results, and we want them now! We need to be able to produce evidence that our efforts to maintain an asset will produce a significant Return on our Investment. For many, this means big changes = big impact. However, if we look at the effects of small changes to not only maintenance activities, but budgets, time and ability, and the willingness of staff to implement said changes, we can observe that small modifications are a more effective and efficient means to achieve higher reliability and maximize the life of our assets. Small changes also provide the flexibility to course-correct without any significant negative impact to the factors mentioned above.

Table 1 - Aging accelaration factor

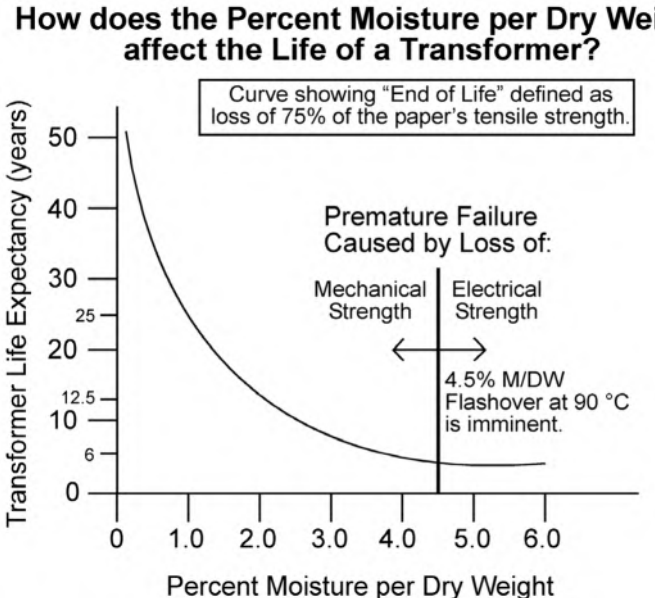
Temperature °C	Age Factor	Temperature °C	Age Factor	Temperature °C	Age Factor
<37	0.0000	65	0.0054	94	0.1813
38	0.0001	66	0.0062	95	0.2026
38	0.0001	67	0.0071	96	0.2263
39	0.0001	68	0.0080	97	0.2526
40	0.0002	69	0.0091	98	0.2817
41	0.0002	70	0.0104	99	0.3141
42	0.0002	71	0.0118	100	0.3499
43	0.0002	72	0.0134	101	0.3897
44	0.0003	73	0.0152	102	0.4337
45	0.0003	74	0.0172	103	0.4823
46	0.0004	75	0.0195	104	0.5362
47	0.0004	76	0.0220	105	0.5957
48	0.0005	77	0.0249	106	0.6614
49	0.0006	78	0.0281	107	0.7340
50	0.0007	79	0.0318	108	0.8142
51	0.0008	80	0.0358	109	0.9026
52	0.0009	81	0.0404	110	1.0000
53	0.0011	82	0.0455	111	1.1074
54	0.0012	83	0.0513	112	1.2256
55	0.0014	84	0.0577	113	1.3558
56	0.0016	85	0.0649	114	1.4990
57	0.0019	86	0.0729	115	1.6565
58	0.0021	87	0.0819	116	1.8296
59	0.0024	88	0.0919	117	2.0197
60	0.0028	89	0.1031	118	2.2285
61	0.0032	90	0.1156	119	2.4576
62	0.0037	91	0.1295	120	2.7089
63	0.0042	92	0.1449	121	2.9845
64	0.0048	93	0.1622	122	3.2865

IEEE C.57.106.1995, Table 1 – Aging acceleration factor (Source: [1])

In the case of transformers, it's important to consider the asset's criticality, health status, and the impact and consequences of failure to the organization. In today's power systems, the average age for an in-service power transformer is 38 years. Many electric power reliability professionals find themselves in situations where they must manage multiple units that include not only "average-aged transformers", but new units and ones that far exceed the average transformer age.
This assortment of transformers possesses great challenges, especially when the age gap of these assets can span ten, fifteen, even twenty years or more. In situations like these, it's imperative to realize that the robust overbuilt transformer of yesteryear and the new, sleek, more streamlined transformer of today each require a different maintenance philosophy.

Knowledge and understanding of the test data joined with experience affords the reliability professional an opportunity to implement big changes in the transformer management program through smaller, more manageable steps.

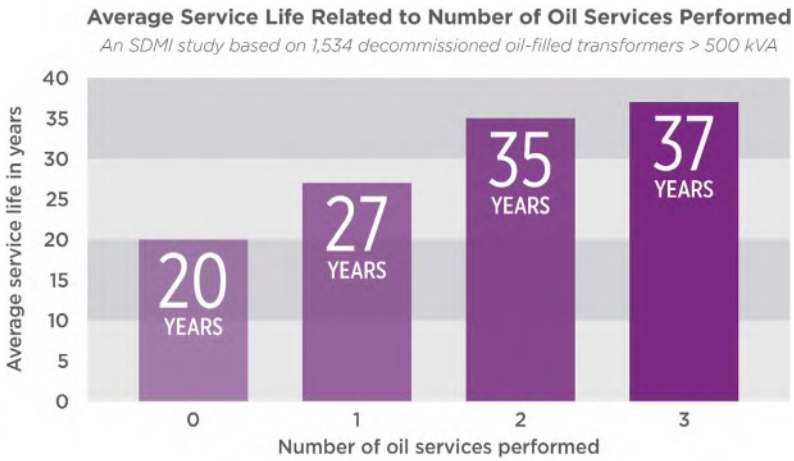
The mediocre maintenance strategy on the over-built unit has sufficed up until this point; mostly, due to an overabundance of caution on the manufacturer's part with an added cushion of solid and liquid insulation beyond the design requirements. This minimalist strategy that has worked for decades is now antiquated, inefficient and harmful to a reliability-focused strategy, as new units require a more conscientious and active approach in their maintenance and management strategies. Small changes in the chemical, mechanical, and electrical evaluations of these assets, on all sides of the age spectrum, can be extremely impactful.



The use of online gas monitors for new and in-service units, customized testing programs for the liquid insulation, the use of appropriate electrical test methods and testing intervals during the transformer's lifecycle, and the adaptation and inclusion of newer evaluation technologies such as Ultrasound and Vibration Analysis are all part of the necessary tasks required to assess a transformer's health and reliability. Yet one must not discount the importance of active participation in organizations dedicated to the advancement of electric power reliability, and, most importantly the establishment of a consistent training and education program for everyone involved in the care of these assets.

Knowledge and understanding of the test data joined with experience affords the reliability professional an opportunity to implement big changes in the transformer management program through smaller, more manageable steps, providing an opportunity to course-correct as needed without significant impact to the asset, the maintenance program, or operations.

Think about this interesting fact: by performing one service, for example: re-inhibiting, moisture reduction, oil reclaiming, etc. on a transformer, you can gain an average of seven years of in-service life on that unit.



Consistency

Once we've developed a plan and begun to implement those changes, it's imperative to remember the next part of our equation: Consistency – Trust the Process. Change occurs when you are motivated and disciplined. Discipline is what is left after motivation leaves the room. In the case of power transformers, we need to have the discipline and wherewithal to resist the temptation of falling back into old maintenance habits. Understanding the "Why" helps us to remain uniform with all our tasks and activities.

Transformer maintenance and management is all about the data. The consistency of transformer testing: chemical and electrical, visual inspections, infrared thermography, and other test data provides us with a baseline of information about the health of the transformer. Over time, the data we accumulate from these tasks becomes information. We couple this with knowledge acquired through training and education efforts and we begin to develop a complete assessment of the health of the transformer. This assessment is then used for trending analysis, industry comparison, predictive maintenance, and planning for end of life.

The ability to avoid turning new habits into complacent tasks, and the act of continuously seeking knowledge is what sets reliability professionals, thought leaders and subject-matter experts apart from the crowd. It's this ability to keep moving forward, routinely evaluate the effects of these small, incremental changes and a consistent and faithful dedication to the process that begins the transition from simply maintaining the asset to a true reliability mindset.

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Time

The third and equally as important addend in this equation is time. You have to be willing to "be in it for the long haul". Theoretically, power transformers have a life expectancy of more than 400 years. I have had the pleasure of being witness to the celebration of several units that have exceeded 100 years of service and are still going strong. Time is our most precious resource and one that we cannot regain. However, in the world of power transformers I like to challenge that last statement. Think about this interesting fact: by performing one service, for example: re-inhibiting, moisture reduction, oil reclaiming, etc. on a transformer, you can gain an average of seven years of in-service life on that unit.

Consider these interesting facts about the transformer's solid insulation system and temperature: we can observe and calculate the temperature interval (increase) that will cut the life of the paper in half; conversely, we can also calculate the temperature interval (decrease) that will double the life of the solid insulation and increase the life of the transformer. Finally, did you know every time you double the moisture content in a transformer you are

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effectively halving the reliable life of that unit? Imagine how much time could be gained on the life of an in-service unit if we started off with a reliability mindset from the very beginning, the design phase.

When it comes to time, it's important to remember to be confident in your decisions, knowledge, and abilities. There are many documents to help you achieve success in your journey, covering everything from the what to the how and even the why. Think about it this way, you wouldn't throw in the towel after one workout at the gym, NO! So why do we regularly implement new programs and processes only to abandon them three months later? It is said "the best things take time". Well, so does Reliability. I'm sure we all remember the lesson from story of the Tortoise and the Hare, slow and steady wins the race.

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The compounding effects of these three factors when done carefully and with intention are what set the reliability professional apart from the average maintenance worker.
A dedication to the art of interpreting data, converting it to information, translating that information into knowledge and eventually into wisdom is a path which all "reliability focused" organizations must take. Fortunately, in today's world of power transformers, we have access to the resources, training, subject matter experts, colleagues, associations, and organizations at our fingertips. With a click of a mouse, the stroke of a keyboard, or a phone call we can easily access communities of electric power professionals and find many potential solutions to our inquiries.

The ability to implement small changes on a consistent basis over a period of time will unify the organization, achieve the intended goals and extend the reliable life of one of the most valuable assets in any electric power system, the transformer. Now, I urge you to go back to the beginning and ask yourself the same two questions again, what is the definition of reliability and how do you maintain an asset's reliability? Your answer should funnel down to three distinct areas: small changes, consistency, and time. These three addends, when given the opportunity, will equal an increase in the reliability of our assets and personnel, and effect positive change in our organization's reliability culture.

References

[1] IEEE C57.91-1995 – IEEE Guide for Loading Mineral-Oil-Immersed Transformers