Technical Note 157

MTBF and the 580 series

Drive design and mean time between failures

Mean time between failures (MTBF) is a mathematical approach to identifying the average time between failures in equipment. Drive manufacturers (including ABB) have a history of providing MTBF data based on calculations of certain drive components, combined with assumed environmental factors, and particular components being replaced as part of a preventative maintenance approach. Depending on the drive manufacturer, results between 20 and 50 years, were published. Realistically, those numbers are not achievable in practice. The goal of this technical note is to “undo” 25+ years of the industry misinterpreting drive MTBF values by first reviewing MTBF and then show how ABB designs and tests the 580 series drives to verify they are best in class. While this paper is based on the 580 series, which is made up of the ACH580, ACQ580, and ACS580, the concepts are applicable to other drive families.

Why is MTBF not the answer?

As previously mentioned, seeing MTBF data published with values greater than 20 years is quite common. Some of the history and past motivation was to publish MTBF values greater than other drives on the market, especially in the commercial HVACR and the Water & Wastewater (W&WW) industries. HVACR and W&WW markets are heavily driven by meeting specifications for both greenfield and brownfield projects. Drive manufacturers consistently tried to publish numbers higher than other drive manufactures, in an attempt to give themselves a competitive advantage in the specification. While the calculations were mathematically and scientifically sound for an ideal laboratory environment, they were not applicable to how drives are applied at most installations. If you ask any facility manager regarding the real-world lifespan of drives, they may have some but not many drives that are still operating after 20-25 years.

One way a drive’s MTBF can be calculated is by looking at the failure rate of microprocessors, opto-couplers, capacitors, IGBTs, diodes, cooling fans, etc. The failure in time (FIT) data for these components is sourced from the component manufacturer based on that component being applied correctly as a stand-alone component. This is the first potential issue with MTBF. How does one know the drive manufacturer applied the component correctly? Perhaps the cooling approach of their drive design does not move as much air across that component as anticipated? Perhaps one drive manufacturer is pushing that device to its limits, while another drive manufacturer is less demanding on that component? This is why a MTBF based on the calculation of only components is unreliable.

Another practical issue is that the MTBF calculation also assumes components like the DC bus capacitors and cooling fans are proactively replaced under a preventative maintenance plan. On smaller drive sizes, changing capacitors is not an economical task when compared to the cost of the overall drive. As a result, items like capacitor replacements rarely happen in most industries. Some sites may be more proactive about cooling fan replacements, but most wait until the drive’s cooling fan fails before replacing it. If the preventative maintenance, including periodic heatsink cleaning, is not done, then the MTBF data for that product is not applicable for the installation.

How to design a robust drive

Designing and producing a robust drive starts with experience. That experience leads to:

- Selection of quality components
- Intelligent design of drive hardware and firmware with a rigorous peer review process
- Accelerated life testing (ALT)
- Highly accelerated life testing (HALT)
- Quality control in manufacturing with optimized factory testing before the drive ships

ABB invests significant resources in making sure quality components are used in the manufacturing of drives. While component FIT data is considered, years of research and development (R&D) experience in component types, manufactures, and component tolerances also come into play. Alternate (second-source) components are held to the same standards as the primary component.

ABB has a global R&D team with specialties in hardware, firmware, and multiple levels of subspecialties. For example, firmware expertise is broken down into topics such as motor control, communications (BACnet), user interface, etc. This level of expertise, along with coordination and cooperation among the teams, includes the sharing of best practices and making sure the years of lessons-learned are applied to future drive designs. ABB invests a significant amount of resources into engineering, about 4% of revenue, which is on the order of $1.2 billion annually.

Knowing how drives fail and the physics of failures also provides insight on how to design a robust drive. Drives ultimately fail due to overstress or wear-out. All new drive designs go through ALT testing to simulate wear and tear. They also go through HALT testing to simulate stress scenarios. Designing a drive that does well in both ALT and HALT testing is a key factor in having a drive that will have a long lifespan.

ALT testing exposes the drive to a variety of different stress levels. These levels and profiles are selected to allow a 6 month test to simulate 10 years of operation. Temperature is the most significant variable in ALT testing. A component operating at a higher temperature will age faster than a component operating at a lower temperature. One example that predicts wear-out time as a function of temperature is the Arrhenius model. While the following rule-of-thumb is an oversimplification of the Arrhenius model and does not consider all the variables covered in the ALT test, for illustration purposes only, one can consider a rule-of-thumb that for every 10° C increase in temperature, an electronic component's lifespan is expected to be reduced in half.

HALT testing has some similarities to ALT, except the stress levels are even higher. A primary goal of the HALT overstress testing is to determine the weakest link within the drive design. The stress levels involved in these tests include temperature, vibration, mechanical shock, voltage, current, over-torquing terminals, humidity, and moisture. Once the component(s) fail, an evaluation is done to determine if those failures are expected and acceptable, or if a component or design change is required. Drive protection features (such as the over temperature fault) are turned off to allow the drive to achieve an operation point that causes component failure. The temperature portion of these tests have been known to get to temperatures where the plastic starts to melt before a component finally fails.

Occasionally, certification testing is brought up as part of a quality or robust drive conversation. For example, UL61800-5-1, which covers topics like breakdown of components testing and short circuit testing. These tests are more about making sure the drive will fail in a safe way than about making sure the drive will have a long life. While these certifications are important, they are not directly tied to lifespan.

Once a drive has been designed, tested, and released to production, each ABB drive manufactured goes through an automated test to confirm the quality of manufacturing and reveal latent failures causing infant mortality at the component level. This test is optimized to use stress (similar in concept to the ALT test) to verify a quality product, yet not to provide so much stress as to negatively impact the overall lifespan of that drive. Reference Technical Note 028 *Burn-in process on 580 series* for more information on this test.

The articles below provide additional details on ABB's design verification and testing approach. The articles go more in-depth on ALT and HALT while also covering additional topics like the physics of failure, reliability demonstration testing (RDT), highly accelerated stress screening (HASS), and ongoing reliability testing (ORT).

- The embodiment of reliability for variable speed drives
- Why do variable speed drives fail and how do we test them?

What lifespan should you expect out of an ABB 580 series drive?

The lifespan of a product is impacted by variables outside the control of the product itself. In the case of a drive, how warm is the ambient temperature? How clean is the air to the drive? If there are air filters, are they replaced when dirty? Will the heatsink be cleaned and cooling fans proactively replaced, or will the drive need to fault on over-temperature before the heatsink is cleaned or a cooling fan replaced? How good is the power quality (sags or swells) from the utility? Is the electrical network prone to voltage spikes, perhaps caused by lightning? Will the control and power terminals be properly torqued during installation and retorqued a year later as part of preventative maintenance? What does the load profile look like? If the drive will be installed at a high altitude or operated at a high switching frequency, has the drive been properly sized/derated? Is this drive running 24 hours a day, 7 days a week, at maximum rated load at maximum rated temperature?

Generally speaking, the design lifetime expectancy of the 580 series drives exceeds 10 years in normal operating conditions, assuming recommended maintenance (per the drive's manual) is followed. A facility management approach can be to budget such that you assume your drives should be replaced every 10 years but do not be surprised to see them running for 15 or more years. In some cases, depending on the application and site conditions, the drive will last 20 years or more. For example, ABB still receives requests asking for assistance to replace existing drives like the ACH400 (1998-2003 era product) with a modern-era ACH580.

Summary

ABB has a long history of designing quality drives. After a rigorous initial review of the drive's initial hardware and firmware design, ALT and HALT testing are used to verify the drive will have a lifespan greater than 10 years in typical installations. Traditional MTBF data suggests drives typically last between 20 to 50 years, which is simply not realistic for the practical installation and application of drives. MTBF calculation methods are not reflective of real-world installations and applications.