Informational Document from Harmonics Limited IDHL-9

Subject: Mean Time Between Failure

ESTIMATING MEAN TIME BETWEEN FAILURE (MTBF) FOR HARMONIC SUPPRESSION SYSTEMS

Harmonic Suppression Systems (HSS) are totally passive units consisting of inductive and capacitive elements connected in a resonant tank circuit. Since there are no active elements, the usual MTBF calculations are not applicable. To determine MTBF for passive units, one must examine the failure mechanisms for each component.

Inductive components

Inductive components are UL component recognized under UL file E182641, project 96NK5886. Components were subjected to thermal testing at full rated current in an enclosed cabinet. The test proceeds until thermal equilibrium is reached, at which point the hot spots, measured by thermocouple, are recorded. To pass this test, the component must stay within the temperature limits for the insulation system being used.

Immediately following the thermal test, the unit is subjected to a Hi-pot test to determine if there has been any insulation failure.

In the case of inductive components used in HSS, the hot spot recorded after thermal equilibrium was reached (4 hours) was 99°C with an ambient temperature of 44°C. Output lead insulation adjacent to the coil was 67°C.

Failures of inductive components are due to thermal breakdown of insulation leading to short circuits. In the case of components tested by UL for HSS, output lead wires, used to connect to the coil, have an insulation rating of 150°C. This is 83 degrees above the highest insulation temperature recorded during the UL thermal testing. At full rated current, the chances of this insulation failing are negligible.

Wire used to wind the inductive elements is ESSEX “Thermatex GP-200.” This insulation has a rated temperature of 200°C and has been thoroughly tested for thermal stability. This product is widely recognized for its thermal stability. The maximum winding wire temperature recorded during the UL thermal testing was 99°C. 100°C is the lowest temperature appearing on the insulation system manufacturer’s thermal stability graph. Extrapolating the thermal stability to 67°C, the wire temperature measured by UL, shows an average life in hours for this wire of <u>at least</u> 500,000 hours or <u>at least</u> 57 years. Again, the likelihood of this wire failing is negligible.

The previous discussion assumes that the HSS is operated at full test current. In actual operation, since the HSS reduces 3rd harmonic neutral currents by more than 90% and since neutral 60 Hz unbalanced currents are quite low, the HSS sees only 10 to 20% of its rated current. Inductive element operating temperatures have not been measured exceeding 50°C and the chance of insulation failure is less than negligible. Based on the thermal stability and integrity of the insulation systems used, it is difficult to postulate a mechanism by which the inductive components could fail during operation.

Capacitive Components

Capacitive components used in the HSS are industrial power capacitors, designed for power factor correction. The design lifetime for these components is at least 100,000 hours at full rated voltage. Capacitors of this type are constructed by winding layers of metalized polypropylene film in a cylindrical coil.

These units are called “self healing” since pinhole breakdowns in the film insulation result in a small short circuit which vaporizes the metal and melts the plastic, thus eliminating the breakdown. “End-of- useful life” is considered to be when enough metal has been lost to reduce the capacitance to 70% of the original value. (Unlike earlier metal-foil capacitors, these units cannot fail by short circuit.)

The cause of these pinhole breakdowns is voltage stress and elevated temperatures. Thus capacitor lifetime is decreased by high voltage and temperature. A convenient rating system for capacitors has been established and is referred to as the volt-ampere rating. This rating is calculated using the formula:

$VA = 6.28\ f\ C\ E^2 x\ 10^{-6}$ where:

f is the frequency in Hz C is the capacitance in µF E is the rated voltage

Using this formula for a 20 kVAR, 240 volt rated cell, as used in the 225 amp HSS, the VA rating is:

$6.28 \times 60 \times 2000 \times (240)^2 \times 10^{-6} =$ 43,407 VA

To determine MTBF for capacitive elements used in the HSSs, one must examine the operating characteristics when the HSS is on line. Under normal operating conditions in the HSS, capacitors are subjected to a voltage of 24-30 volts. Most of this voltage is 3rd harmonic (180 Hz.) Using the same formula to determine the actual operating VA Load on the HSS capacitor one obtains:

$6.28 \times 180 \times 2000 \times (30)^2 \times 10^{-6} =$ 2,035 VA

Since the operating VA load determines the stress on the capacitor, it is plain to see that the capacitor in the HSS is stressed to only 5% of its design level. (Reduced stress is due to the low operating voltage, a squared term in the equation.)

With design lifetime of 100,000 hours at rated voltage and temperature stress, the capacitor failure rate in the, at 5% of the rated voltage and temperature stress, is negligible.

Transformers

“TransMax” products combine an HSS with a service transformer to provide a single- installation package. Transformers are custom manufactured for Harmonics Limited and are dry type, 115°C temperature rise, copper wound, with electrostatic shield and 220°C insulation system. As is the case with inductive components, transformer failure occurs due to insulation failure caused by excessive temperature.

ANSI/IEEE C57-96-1989 provides guidance for determining transformer life expectancy. The guide provides a graph relating life hours to hot-spot temperature.

Transformers rated for 115°C temperature rise are wound with larger wire than the standard 150°C rise transformer and contain more steel in the core to reduce flux density. In addition, such transformers have an overload capacity of 11% without reducing the life expectancy or service reliability. However, when operated under normal loading conditions, such transformers have increased operating efficiency and extended lifetime. Hot-spot temperature will be lower than that for a standard transformer.

A typical hot-spot temperature for a 115°C transformer of the type used for TransMax is 150°C. With the ANSI graph it can be determined that at this temperature the expected lifetime of this transformer would exceed 1 million hours. Even if the hot-spot reached 200°C (unlikely) the lifetime would still exceed 500,000 hours. This component can certainly be expected to have a lifetime in excess of 50 years.

All components used in any HSS have been chosen based on the requirement that failure of the unit is intolerable. After examining the available lifetime data on each of the components, one must conclude that the HSS in all configurations is an extremely reliable and long-lived product. Based on component lifetimes, one would expect that the MTBF for this product is well in excess of 50 years.

To learn more about how our products can protect your facility, and save you energy, contact:

Harmonics Limited Customer Support, (800) 892-3755
Customer_Service@HarmonicsLimited.com