TRICONEX

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United States Nuclear Regulatory Commission
Washington, DC 20555

Subject: Nuclear 1E Qualification of the TRICON TMR Programmable Logic Controller (PLC) – Additional Information related to Component Aging Analysis

References:
1. EPRI TR-107330, Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants.
2. Qualification Summary Report, Triconex Document No. 7286-545, revision 1.
3. Project Number 709

Gentlemen:

In Reference 1, the EPRI specification document governing the Triconex Nuclear 1E Qualification Project, a component aging analysis (per section 4.7.8.2) was required to be performed as part of the qualification effort. Section 8.0 (Documentation) of the specification, did not require submittal of a specific document for this aging analysis; rather, it required that the results of the aging analysis be incorporated into the Final Summary Report/Application Guide. Accordingly, the aging analysis was performed and the results were incorporated into the Qualification Summary Report, 7286-545, Revision 1. This document was transmitted to the NRC on October 2, 2000.

Based on our recent discussions with the Staff, we believe it would be beneficial to provide some supplemental background information on component aging analysis (1) as it relates to our design process and (2) as it pertains to the Triconex Nuclear Qualification Project.

As part of the process of assembling information for the Qualification Summary Report last year, a component aging evaluation was performed. All components in the TRICON were considered. Environmental conditions encompassing those specified in Reference 1, section 4.3.6 were also considered. Since aging considerations have always been an integral part of Triconex design and development activities, the bulk of the analysis work had already been done. Information on component failures and projected design life is readily available within Triconex. The conclusions reached after reviewing this information, was that only two components had any significant aging considerations; the back-up batteries and the electrolytic capacitors in the power supplies. These conclusions were reported in section 4.12 of Reference 2.

Also, consistent with TR-107330 section 4.7.8.2, guidance from IEEE 323, section 6.2.1 was followed for providing in-service surveillance and maintenance recommendations. Appendix B, section 6.3 of the Qualification Summary Report provides specific maintenance considerations to account for the potential lifetime limitations of the batteries and electrolytic capacitors. Adherence to these recommendations will assure that no age related component failures present a safety concern with the qualified TRICON systems.

Attached is a Triconex Component Aging Analysis discussion provided by our Engineering Department. If you have any questions or wish further information, please contact me at (281) 360-6401 or Mr. Michael Phillips at (949) 885-0711.

Sincerely,

Tracy D Sledge for JTM

J. Troy Martel, P. E.
Triconex Nuclear Qualification Project Director

Enclosure
cc: L. Raynard Wharton, NRC
P. Loeser, NRC

Attachment 1 – Triconex Component Aging Analysis

COMPONENT AGING ANALYSIS FOR THE TRICON PRODUCT

When the TRICON was first designed a number of years ago, aging was an important factor in the design, as it was well known that industrial control equipment must live a long life. In February of last year (2000) in connection with the Nuclear Qualification Project, we revisited this issue and reviewed the design of TRICON for potential aging problems. All components in the TRICON were considered. Our conclusions are as follows:

Due to the triple-modular-redundant architecture and comprehensive diagnostics of the TRICON, a failure of any nature including aging is diagnosed and reported to the control system. The system provides error-free uninterrupted control while notifying the system that maintenance is required. The design of all the modules was reviewed to ensure that the components used were within the guidelines of "Military Handbook Reliability Prediction of Electronic Equipment MIL-HDBK-217F". We use the Triconex Engineering Procedure EDM-64.00 to predict the reliability of the components in our product and these were derived from the above military standard (see attached Table 1).

The TRICON chassis backup batteries are the most age-limited component in the system. All TRICON batteries are alarmed, and the replacement is covered in the TRICON P & I Guide. Time specified for replacement is half of the expected lifetime. We reviewed the remaining parts in the system.

Of the remaining parts in the system, the aluminum electrolytic capacitors in the power supply are subject to a wearout mechanism - electrolytic evaporation - which causes the hazard rate to increase with time. This component, although still with a predicted life of greater than 20 years, is, after the battery, the shortest life part in the system. The mean-time-to-failure (MTTF) (see Table 2) is based on many factors including temperature and stress. Since our power supplies are typically running at less than half their rated loads, this component should have long life. Failure of a capacitor and consequent failure of power module still allows the system to maintain operation. If both power supplies fail (a pathological condition) this will result in a fail-safe condition (outputs going to a de-energized state). All the other components in the system have life times that greatly exceed 20 years as shown in the attached short-form failure prediction table. The optoelectronics in the system are also subjected to aging. The LED indicators on the front of the module will dim slightly over time with no impact on system function. The light emitting part of our solid-state relays and opto-isolators also have slight degrading over time, but in the original design, the worst case CTR (current transfer ratio) over a minimum of 20 years was considered, and there was no degradation of the system.

08/30/01
Paul Groner Date
Manager, Engineering
(Prepared)

8/30/01
G. Hufton Date
Director, Hardware Development
(Reviewed/approved)

Table 1: TRICONEX SHORT FORM FAILURE PREDICTIONS (Failures / Million Hours)*

Capacitors, Aluminum CE	.029
Capacitors, Ceramic CKR	.004
Capacitors, Plastic CRH	.002
Capacitors, Tantalum CSR	.002
Circuit Breakers	.060
Connectors, Coaxial	.012
Connectors, Rack & Panel	.011
Diodes, Current	.040
Diodes, General Purpose	.028
Diodes, Power / Schottky	.022
Diodes, Varistor	.023
Diodes, Volt Reg.	.024
Electronic Filters	.270
Emitters / LEDs	.001
Fuses	.010
IC Sockets	.002
Inductors	.002
Opto - Isolators	.070
PCBs	.053
Photodetectors	.029
Quartz Crystals	.032
Relays	.430
Resistors, Discrete RL,RN,RC	.003
Resistors, Film Power RD	.025
Resistors, Wirewound Power RW,RWR	.031
Resistors, Wirewound Precision RB,RBR	.018
Resistors, Network RZ	.007
Solid State Relays	.500
Switches, Rotary	.560
Switches, Toggle	.001
Thermistor RTH	.320
Thyristors / SCRs	.020
Transformers	.023
Transistors, Bipolar	.001
Transistors, Bipolar Power	.042
Transistors, MOS	.099

gates(digital)/transistors(linear)		**100**	**300**	**1000**	**3000**	**10000**	**30000**	**60000**
IC, CMOS	Digital	.006		.010	.019	.049	.084	.130
IC, Bipolar	Digital	.004		.006	.011	.033	.052	.075
IC, CMOS/Bipolar	Linear	.010	.017	.033	.050			
IC, CMOS	PLA	.005				.006	.006	.006
IC, Bipolar	PLA	.006		.011	.022			
IC, CMOS	Microprocessor	.048(8bit)		.093(16bit)		.190(32bit)		
IC, Bipolar	Microprocessor	.028(8bit)		.052(16bit)		.110(32bit)		

IC, Memory	**MOS/EE/P/ROM**	**MOS/DRAM**	**MOS/SRAM**	**BIPOLAR/P/ROM**	**BIPOLAR/SRAM**
16K	.005	.004	.008	.010	.008
64K	.006	.006	.014	.017	.012
256K	.007	.007	.023	.028	.018
1M	.012	.011	.043	.053	.033

*ASSUMPTIONS:

1. MIL-HDBK-217F APPENDIX A (NOTICE 1 INSERTED)
2. 30C ambient (except resistors @ 40C, discretes @ Tj = 60C).
3. Parts run typically @ stress of .5 i.e. 1/4W dissipation in 1/2 W resistor.
4. Quality factor = 8 for IC; 1 other - commercial quality M. This is set in Triconex parts master file.
5. Environmental factor = 1 benign environment.
6. Ref. EDM 64.00

Table 2 – MTBF/MTTF Data

Triconex #	Component	MTBF/million hrs	MTTF in years
1200xxx-001	Capacitors, Aluminum CE	0.029	3936
1200xxx-001	Capacitors, Ceramic CKR	0.004	28539
1200xxx-001	Capacitors, Plastic CRH	0.002	57078
1200xxx-001	Capacitors, Tantalum CSR	0.002	57078
1630xxx-001	Circuit Breakers	0.06	1903
1500xxx-001	Connectors, Coaxial	0.012	9513
1500xxx-001	Connectors, Rack & Panel	0.011	10378
1300xxx-001	Diodes, Current	0.04	2854
1300xxx-001	Diodes, General Purpose	0.028	4077
1300xxx-001	Diodes, Power / Schottky	0.022	5189
1300xxx-001	Diodes, Varistor	0.023	4963
1300xxx-001	Diodes, Volt Reg.	0.024	4756
1320xxx-001	Electronic Filters	0.27	423
1330xxx-001	Emitters / LEDs	0.001	114155
1410xxx-001	Fuses	0.01	11416
1500xxx-001	IC Sockets	0.002	57078
1320xxx-001	Inductors	0.002	57078
1000xxx-001	Opto – Isolators	0.07	1631
7300xxx-001	PCBs	0.053	2154
1000xxx-001	Photodetectors	0.029	3936
1300xxx-001	Quartz Crystals	0.032	3567
1300xxx-001	Relays	0.43	265
1100xxx-001	Resistors, Discrete RL,RN,RC	0.003	38052
1100xxx-001	Resistors, Film Power RD	0.025	4566
1100xxx-001	Resistors, Wirewound Power RW,RWR	0.031	3682
1100xxx-001	Resistors, Wirewound Precision RB,RBR	0.018	6342
1100xxx-001	Resistors, Network RZ	0.007	16308
1000xxx-001	Solid State Relays	0.5	228
1400xxx-001	Switches, Rotary	0.56	204
1400xxx-001	Switches, Toggle	0.001	114155
1300xxx-001	Thermistor RTH	0.32	357
1300xxx-001	Thyristors / SCRs	0.02	5708
1440xxx-001	Transformers	0.023	4963
1300xxx-001	Transistors, Bipolar	0.001	114155
1300xxx-001	Transistors, Bipolar Power	0.042	2718
1300xxx-001	Transistors, MOS	0.099	1153
1000xxx-001	IC, VLSI (using worst case numbers)		
1000xxx-001	IC, CMOS	0.01	11416
1000xxx-001	IC, Bipolar	0.006	19026
1000xxx-001	IC, CMOS/Bipolar	0.05	2283
1000xxx-001	IC, CMOS	0.011	10378
1000xxx-001	IC, Bipolar	0.011	10378
1000xxx-001	IC, CMOS	0.19	601
1000xxx-001	IC, Bipolar	0.11	1038
	IC, Memory (using worst case numbers)		
1000xxx-001	16K	0.01	11416
1000xxx-001	64K	0.017	6715
1000xxx-001	256K	0.028	4077
1000xxx-001	1M	0.053	2154