Project:	**TRICON v10 NUCLEAR QUALIFICATION PROJECT**

APPLICATION GUIDE

Document No.: 96000164-545
Appendix B

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1.0 INTRODUCTION

This report provides requirements for applying the Triconex TRICON Programmable Logic Controller (PLC) in nuclear power plant systems classified as Safety Related and Important to Safety. The requirements presented in this document are necessary to maintain the environmental qualification of the TRICON, and supplement the standard manufacturer's recommendations provided by Triconex for application of the TRICON. These are documented in the Triconex Planning and Installation Guide (Reference 6.3). The "as-tested" configuration of the TUT is documented in the Master Configuration List (Reference 6.20) and the system drawings (References 6.21 thru 6.34).

2.0 SYSTEM CAPABILITIES

2.1 The TRICON Programmable Logic Controller

The TRICON Programmable Logic Controller (PLC) with the TriStation 1131 Development Workstation provides a suitable platform for implementation of safety-critical digital Instrumentation and Control systems. The Triple Modular Redundant design of the TRICON PLC has been shown to provide a high degree of reliability in addition to high availability. These characteristics make the TRICON platform particularly suited to nuclear safety-related applications. The TriStation 1131 Development Workstation, when used as described in this guide, provides a suitable means for developing and maintaining application software and configuring the TRICON system.

A detailed description of the TRICON PLC and TriStation 1131 is provided in Section 4.1 of the EQ Summary Report (Reference 6.7).

Hardware type tests were performed with Version 10.2.1 of the TRICON system. However, the specific version of the TRICON system supplied for nuclear plant applications may be a later version. If versions later than Version 10.2.1 are supplied for nuclear safety-related applications, the qualification basis described in this report will be augmented with technical evaluations or additional testing based on the requirements established in Section 6.8 of IEEE Standard 323-1974.

2.2 Key System Features

This section provides an overview of the key features of the TRICON PLC.

A. The TRICON PLC is constructed of individual modules, installed in a rack mount chassis. There are certain modules that are required, such as power supplies and Main Processors. The remaining modules, number of chassis required, and locations of the modules are configurable.

B. The TRICON PLC is designed as a Triple Modular Redundant (TMR) system and has been demonstrated to be resistant to single, active failure mechanisms. The power supplies are dual redundant, with each supply capable of providing all power requirements to the chassis in which it is installed. The backplane communication paths are triple redundant. The input and output modules are triple redundant internal to the module. Three separate Main Processor modules are required. Communication modules to external systems may be single train or dual redundant. For a one-year periodic test interval, the mean time to failure due to a spurious trip (MTTFspurious) is 310.2 years resulting in an overall availability of 99.9991%. For the same test interval, the average probability of failure on demand (PFDavg) is 6.577×10^{-6} resulting in a Safety Availability of 99.9993%.

C. The TRICON PLC was designed to be used as a single channel Emergency Shutdown System or Safety Instrumentation System. Industries other than nuclear make use of only a single channel safety system. The TRICON will be used in the nuclear industry in a mode retaining the existing redundancy provided in separated channels, divisions, and trains.

D. The TRICON PLC provides conservative alarming of internal faults. Rather than fail to identify internal faults, the TRICON identifies possible faults for resolution by maintenance. The TRICON does not attempt a program-based determination of the safety consequences of a given fault condition.

E. Faults on a TRICON PLC are not indicators of system failure. Rather, the system continues to operate through faults, based on the TMR design. Faults are indicators that maintenance action is required to restore complete redundancy. There are no known, identified, active single points of failure within a TRICON PLC except Software Common Cause Failure. While the TRICON PLC can tolerate a single fault on every module and continue to correctly implement the application program, prompt repair decreases the already remote possibility of multiple faults combining into a failure. From review of the system, there is a large class of faults where multiple faults may exist on a single module with no adverse effect on system operability.

F. The TRICON PLC uses triplicated, isolated analog and digital inputs, sampled from a single input point. Each input is voted prior to use in the application software. The median analog value is selected for use. Faults on any single portion of the input circuit will be alarmed and that faulted input will not be used by the application software.

G. The TRICON PLC qualified digital outputs provide quad voting circuits on each output. Each output is voted from the three separate output channels. The supervised digital outputs check for current flow and appropriate voltage levels. Output voter diagnostics are performed to detect failures in the voter circuit and to detect shorts or opens on the expected field load to be driven by the output. Faults will be alarmed.

H. The TRICON PLC analog outputs provide three separate digital to analog conversion channels on each point. The current flow from each analog output is measured. Faults in a given digital to analog converter channel will be alarmed and the output module then copes with the fault.

I. A list of qualified TRICON hardware is provided in the main body of the EQ Summary Report.

3.0 SYSTEM DESIGN GUIDANCE

3.1 Operational Constraints

Specific operational constraints that apply to the use of the TRICON system in nuclear safety-related applications include the following:

A. The TRICON keyswitch shall be in the RUN or REMOTE position when the TRICON is not bypassed and thus performing safety related functions. If the TRICON is not in a bypassed state, alarms must occur if the keyswitch is in any position other than RUN or REMOTE.

B. The STOP position on the keylock switch shall be disabled in the system software configuration to preclude inadvertently stopping the program.

C. Repairs to the TRICON must be performed in an expeditious manner. Main Processors should not be left in a faulted state for extended periods. Operation in single Main Processor mode should be minimized and should not be longer than one day to minimize risk of masking other faults. The TRICON has limited diagnostic capabilities in dual processor mode. A second TRICON fault might cause the outputs to go to the safe, de-energized state. Length of times allowable for running in dual or single mode may be calculated using Markov modeling by pre-determination of minimum acceptable probability to fail on demand.

D. Separate sections of this Application Guideline provide specific recommendations for Maintenance Overrides and Communication with External Systems.

3.2 Power

Power supply design considerations that are specific to the TRICON system include the following:

A. Redundant chassis power supplies shall be installed in each chassis.

B. The 120 Vac chassis power supply has been validated to operate successfully over input ranges of 85 V ac to 140 Vac and 47 Hz to 63 Hz. The 24 Vdc chassis power supplies have been validated to operate successfully over input ranges of 22 Vdc to 31 Vdc.

C. The 120 V ac chassis power supplies provide hold-up times on power interrupt of at least 40 milliseconds when installed as the only chassis power supply or when installed in combination with a second chassis power supply. The 24 Vdc chassis power supplies provide no hold-up on power interruption. Note that with redundant power supplies, hold up time is important only for power interruptions with the redundant power source turned off.

3.3 Software Application Development Requirements

A. The use of a complete software life cycle in all application development is required.

B. If Structured Text is used in developing safety related applications, the programmer shall ensure that loops within the Structured Text are minimized.

C. Any network cabling should be implemented in a manner to assure that multiple division, channel, or train connections are not possible. The TRICON PLC must be applied in a manner that maintains existing channel independence, maintains system integrity, and meets the single-failure criterion.

D. To support the reliability and availability of cross division communications, it is recommended that peer-to-peer safety related networks use redundant communication links on redundant TCM for each peer-to-peer network. Within a division or channel, redundancy should be considered and evaluated, and may not be required to meet safety, reliability, availability, and maintainability goals. Redundant messages shall be passed through each TCM, alarming when one link fails to produce valid messages for several message periods, and taking the appropriate failure action when both links are unavailable. This also requires application features that detect, deal with, and annunciate faults and failures. The application software must also detect and restore redundant communication links after repairs to a failed TCM or communication link.

E. The communication between the TriStation 1131 PC and the TRICON PLC shall be over a communication link using the IEEE 802.3 protocol or equivalent, to gain the protection of CRC checks on transmitted messages.

F. Safety related and nonsafety related communication links shall not be mixed on any communication module.

G. The TRICON keylock switch shall be in the RUN or REMOTE position when the TRICON is not bypassed and thus performing safety related functions. If the TRICON is not in a bypassed state, alarms must occur in the control room if the keylock switch is in any position other than RUN or REMOTE. The REMOTE or RUN position still allows a device communicating with the TRICON, such as a TriStation 1131, Modbus Master, or Distributed Control System, to set variables within the TRICON. In the RUN position, the TRICON application must implement the appropriate gated access function to allow writes into the TRICON application from the external device, into variables configured by the TRICON for remote setting. In the REMOTE position, a device communicating with the TRICON can set variables configured by the TRICON for remote setting. Neither the RUN nor the REMOTE position allows for application program logic changes by the external device.

H. The STOP position on the keylock switch shall be disabled in the system software configuration to preclude inadvertently stopping the program.

I. TRICON internal self-tests and diagnostics provide reasonable coverage of the system. However, surveillance testing is still required and shall be designed by the end user to validate correct operation of the entire plant system including the TRICON.

J. The application program shall provide an integrity check for each message such as a CRC-32, separate from the TCM. This function is already provided when using the TRICON peer-to-peer communication.

3.4 Communication Requirements

A. The TCM is treated as a black channel (defined as a “communication channel without all the available evidence of design or validation according to IEC 61508” in IEC 61784-3/CD (Reference 6.36), as opposed to a white channel “in which all relevant hardware and software components are designed, implemented, and validated according to IEC 61508”).

B. For all safety to safety related equipment links, application software at each end, external to the TCM, has complete responsibility for ensuring the integrity of the communication link. The extra protection provided by the TCM is not credited, but adds to the overall communication link reliability.

C. The safety related communication channels between TRICONs cannot be reached by outside or nonsafety related communication channels. This requires that the safety related communication channels not be connected as virtual networks on switches, hubs, routers, or other equipment that has any connection to nonsafety equipment. If there is any communication between the safety related TRICON network and any nonsafety related equipment, the TCM is credited with performing the function of a one-way isolator when set in the Read-Only configuration, in that all of the preprogrammed Read-Only and Diagnostic data are routed by the safety related application running in the Main Processor to the firmware in the TCM. The TCM then handles all requests for any of this data and no requests for data are transmitted from the TCM to the Main Processor. This then protects the safety grade network from all postulated forms of attack from external systems. For the likely applications of the TRICON, with minimal exception, there is no foreseen need to have any data provided by nonsafety related computing equipment back into the TRICON. In addition, the TRICON protects itself appropriately by configuration.

D. No credit is taken for the CRC or other communication message protection provided by the TCM software.

E. Features are provided in the messages to enhance detection of various faults and failures listed below.

1) Periodic message transmission intervals shall be based on the needs of the safety process.

2) All data shall be transmitted in each message, to ensure that the minimum channel loading is the same as the maximum communication channel loading, which occurs at all times.

3) The application shall provide a protocol with message acknowledgement and negative acknowledgement. Credit cannot be taken for actions performed by the TCM software for nuclear safety. The TRICON itself provides this functionality through the use of the Peer-to-Peer communications protocol for safety data communications between TRICONs.

3.5 Setpoint Accuracy Calculations

An analysis was performed to provide a single concise listing of the accuracy specifications of the Triconex TRICON control system. The specifications documented are those typically used by nuclear industry users for calculating instrument measurement uncertainties and establishing critical control setpoints.

The Triple-Modular Redundant architecture of the TRICON along with its continuous diagnostics and self-calibration features eliminates many of the typical error sources found in standard instrumentation. Component / module failure, channel failures, or communication failures at the Input, Output, or Main Processor Module level will be corrected / compensated for by the system's ability to detect transient/steady state errors, and to take appropriate corrective actions online through the system's hardware and software voting mechanisms.

Tables 1 thru 3 that follow document the Reference Accuracy specifications, for each of the analog I/O modules included in the Triconex Tricon PLC qualification program.

Table 1 - I/O Module Accuracy Specifications

I/O Module Type	Model Number	Reference Accuracy(Note 1)
0-10V Analog Input	3701	< 0.15% of FSR (Volts) 0° to 60° C (Note 2 & 3)
0-5V or 0-10V Analog Input (16 Inputs)	3703E	< 0.15% of FSR (Volts) 0° to 60° C (Note 2 & 3)
4-20 mA Analog Output	3805E	< 0.25% (in range of 4-20 mA) of FSR (0-22mA) 0° to 60° C
Thermocouple Input J,K,T,E	3708E	See Table 2
Pulse Input	3511	@ 1,000 Hz to 20,000 Hz = ± 0.01% @ 100 Hz to 999 Hz = ± 0.1% @ 20 Hz to 99 Hz = ± 1.0%
0-5V Analog Input or -5 to +5V Differential	3721	< 0.15% of FSR 0° to 60° C (Note 2 & 3)

1. Reference Accuracy includes all the components of accuracy (repeatability, hysteresis non-linearity, and dead band). The manufacturer guarantees that the performance of the module meets specifications. This performance has been verified by testing performed on all modules during production (Reference 3.12). Typically, field application of the modules with respect to calibration accuracy's is more stringent than the specified accuracy. Therefore, Reference Accuracy values are considered to be a 95% or better probability value with a 95% or better confidence level.

2. On current loop inputs, a 0.01% precision resistor is used on the input termination to convert the current signal to a voltage reading (250 ohm for 0 -5 VDC or 500 ohm for 0-10 VDC). This is not included in the accuracy of the module.

3. FSR = Full Scale Range

Table 2 - Reference Accuracy of Model #3708E Thermocouple Input Module

TC Type	Temperature Range	Reference Accuracy (Notes 1 and 2) @0-60°C (32-140°F)	
		T_a=25°C (77°F)	T_a=0-60°C (32-140°F)
		Typical	Maximum
J	-150 to 0°C (-238 to 32°F) 0 to 760°C (>32 to 1400°F)	±1.7°C (±3.0°F)	±5.0°C (±9.0°F) ±3.1°C (±5.5°F)
K	-150 to 0°C (-238 to 32°F) 0 to 1251.1°C (>32 to 2284°F)	±2.3°C (±4.0°F)	±4.5°C (±8.0°F) ±3.9°C (±7.0°F)
T	-161 to 0°C (-250 to 32°F) 0 to 400°C (>32 to 752°F)	±1.7°C (±3.0°F)	±4.8°C (±8.5°F) ±2.5°C (±4.5°F)
E	-200 to 0°C (-328 to 32°F) 0 to 999°C (>32 to 1830°F)	±1.7°C (±3.0°F)	±4.5°C (±8.0°F) ±2.8°C (±5.0°F)

1. Reference Accuracy includes all the components of accuracy (repeatability, hysteresis, non-linearity, and dead band). The manufacturer guarantees that the performance of the module meets specifications. This performance has been verified by testing performed on all modules during production (Reference 3.12). Typically, field application of the modules with respect to calibration accuracy's is more stringent than the specified accuracy. Therefore, Reference Accuracy values are considered to be a 95% or better probability value with a 95% or better confidence level.

2. Accuracy specifications account for errors related to reference-junction compensation but do not account for errors caused by temperature gradients between the temperature transducers and thermocouple terminations. The user is responsible for maintaining a uniform temperature across the thermocouple termination module.

Table 3 - Reference Accuracy of Analog Devices Signal Conditioners

Signal Conditioner Type	Model Number	Reference Accuracy (Note 1)
AD7B34CUSTOM, RTD Signal Converter, 200 ohm Pt., 0 – 600°C	1600083-600	+/- 0.11% span
AD7B34CUSTOM, RTD Signal Converter, 200 ohm Pt., 0 - 200°C	1600083-200	+/- 0.2% span
AD7B340401, RTD Signal Converter, 100 ohm Pt., 0 - 600°C	1600024-040	+/- 0.1% span
AD7B340301, RTD Signal Converter, 100 ohm Pt., 0 - 200°C	1600024-030	+/- 0.15% span
AD7B340201, RTD Signal Converter, 100 ohm Pt., 0 - 100°C	1600024-020	+/- 0.2% span
AD7B340101, RTD Signal Converter, 100 ohm Pt., -100 to +100°C	1600024-010	+/- 0.15% span
AD7B300201, RTD Signal Converter, 0 – 100 mV	1600082-001	+/- 0.1% span

1. Reference Accuracy includes all the components of accuracy (repeatability, hysteresis, and non-linearity).

3.6 Error Reporting and Tracking

Triconex has always had formal error tracking and recording systems for industrial safety critical issue notification. Errors are classified according to severity, with Product Alert Notices (PAN) being the most significant, and Technical Advisory Bulletins (TAB) and Technical Application Notes (TAN) being of lesser significance. Product Alert Notices document conditions that may affect the safety of the application. It is essential that all current PANs, TABs and TANs be reviewed before starting application development, and that the system be kept up-to-date with any newly released PANs, TABs or TANs as appropriate.

4.0 ENVIRONMENT AND LOCATION

Specific requirements pertaining to the environment in which a safety-related TRICON system is located are discussed in this section. These environment and location requirements are based on the results of the qualification testing and supplement manufacturer's recommendations in the Triconex Planning and Installation Guide (Reference 6.3). The configuration of the Tricon was chosen to represent worse case conditions.

4.1 Mounting

A. The seismic qualified TRICON chassis requires use of the standard mounting brackets on the front of the chassis as well as the additional standard mounting brackets at the rear of the chassis.

B. Seismic mounting details for all qualified TRICON hardware is provided on Triconex Drawing No. 9600164-102, "Generic Qualification System Equipment Mounting Details." A copy of this drawing is included as Attachment 2 to the Seismic Test Report, Triconex Report Number 9600164-526. All fastener torque values are indicated on Triconex Drawing 9600164-102 (Reference 6.22). The mounting uses standard TRICON front and rear chassis mounting brackets and fastener hardware.

C. Any unused module slots shall be covered with module slot covers.

D. The maximum unsupported length of ETA interface cable shall be in accordance with Triconex Drawing 9600164-102 (Reference 22).

E. Chassis-to-chassis communication (I/O Bus) cabling must be installed in such a way as to preclude susceptibility to IEC 61000-4-6: Immunity to Conducted Disturbances Induced by Radio-Frequency Fields, and IEC 61000-4-16: Immunity to Conducted Common Mode Disturbances in the Frequency Range 0 Hz to 150 kHz.

4.2 Radiation Fields

Radiation testing of the TRICON was performed in accordance with the requirements of EPRI TR-107330 and IEEE Standard 323-1974. The TRICON met all applicable performance requirements after application of the radiation test conditions. The radiation test included the withstand capability of the TRICON to a mild environment radiation exposure of 1000 rads integrated over a 40 year period, plus margin, from a Cobalt-60 source.

4.3 Temperature and Humidity

A. Environmental testing of the TRICON was performed in accordance with the requirements of EPRI TR-107330 and the guidance provided in IEEE Standard 381-1977. The TRICON met all applicable performance requirements during and after application of the environmental test conditions. The environmental test included high temperatures of 140° F and 95% relative humidity (RH) and low temperatures of 32° F and 5% relative humidity. The temperature and humidity profile applied during environmental qualification testing of the TRICON PLC is shown in Figure 7-1 of the Environmental Test Report, Triconex Report Number 9600164-525 (Reference 6.13).

4.4 Seismic Acceleration Limits

Seismic testing was performed in accordance with the requirements of EPRI TR-107330, Section 4.3.9, and IEEE Standard 344-1987.

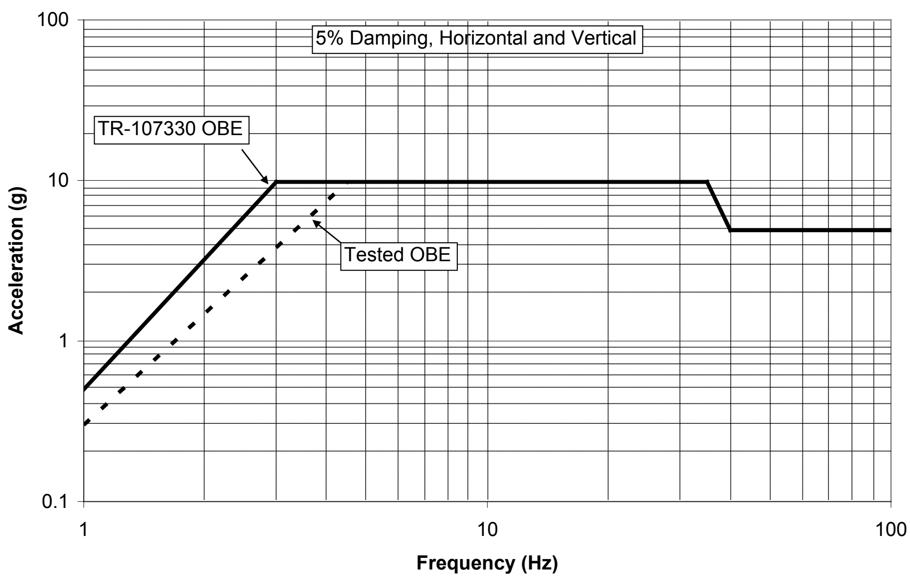

Figure 4-1

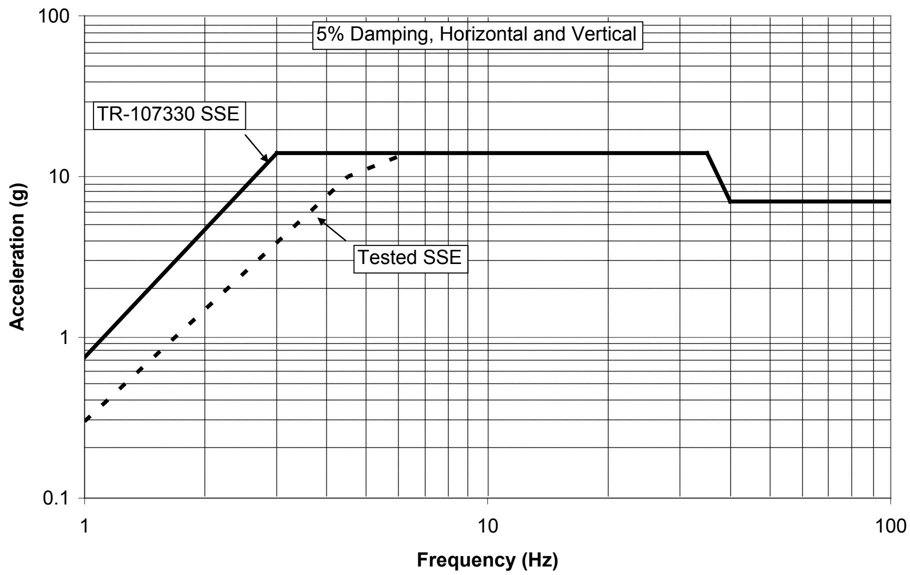

Figure 4-2

A. Seismic testing demonstrates that the TRICON is qualified as a Category I seismic device within the test limits shown on Figure 4-1 and Figure 4-2. Due to limitations of the seismic test table, the five OBE tests and the SSE test of the TRICON were performed using a test response spectrum (TRS) that did not envelope the required response spectrum (RRS) below 4.5 Hz for the OBE and 6.3 Hz for the SSE, shown in Figure 4-1 and Figure 4-2. A plant-specific evaluation will be needed to determine whether the as-tested limits bound the plant seismic acceleration requirements. If not, additional evaluation or seismic testing may be required.

B. Monitoring for chatter of the chassis alarm contacts during seismic testing was not done as a result of utilizing an interposing relay installed in the contact monitoring circuit. Therefore these contacts are not seismically qualified.

4.5 EMI/RFI Compatibility

EMI/RFI Testing of the TUT was performed to the requirements of Sections 3 and 4 of NRC Regulatory Guide (RG) 1.180, Rev. 1 (Reference 6.2). Section 3 of NRC RG 1.180 addresses EMI/RFI emissions testing. Section 4 of NRC RG 1.180 addresses EMI/RFI susceptibility testing. Each section endorses both Military Standard MIL STD 461E series and International Electrotechnical

Commission (IEC) 61000 series EMI/RFI test methods. The qualifier has the option to use either series of test methods, although NRC RG 1.180, Rev. 1 stipulates that for emissions or susceptibility testing, the chosen series of test methods must be applied in its entirety (i.e., there should be no selective application or mixing of the MIL-STD and IEC test methods) The maximum frequency for emissions and susceptibility test was 1 GHz, since the maximum intentionally generated frequency of the Tricon is 100 MHz (Reference 6.2, Section 6 and Reference 6.14).

A. Test Methods

EMI/RFI emissions testing of the TUT included both radiated and conducted emissions testing done to the following MIL-STD-461E series test methods specified in Section 3 of NRC RG 1.180, Rev. 1:

- MIL-STD-461E, Test Method CE101, Conducted Emissions, Low Frequency (30 Hz to 10 kHz), AC and DC Power Leads
- MIL-STD-461E, Test Method CE102, Conducted Emissions, High Frequency (10 kHz to 2 MHz), AC and DC Power Leads
- MIL-STD-461E, Test Method RE101, Radiated Emissions, Magnetic Field (30 Hz to 100 kHz), TUT Surfaces and Leads
- MIL-STD-461E, Test Method RE102, Radiated Emissions, Electric Field (2 MHz to 1 GHz), Antenna Measurement

EMI/RFI susceptibility testing of the TUT included both radiated and conducted susceptibility testing done to the following IEC 61000 series test methods specified in Section 4 of NRC RG 1.180, Rev. 1:

- IEC 61000-4-3, Radiated Susceptibility, High Frequency (26 MHz to 1 GHz), Antenna Exposure
- IEC 61000-4-6, Conducted Susceptibility, Radio Frequency (150 kHz to 80 MHz), Power and Signal Leads
- IEC 61000-4-8, Radiated Susceptibility, Power Line Frequency (60 Hz) Magnetic Field, Helmholtz Coil Exposure
- IEC 61000-4-9, Radiated Susceptibility, Pulsed Magnetic Field, Helmholtz Coil Exposure
- IEC 61000-4-10, Radiated Susceptibility, Damped Oscillatory Magnetic Field (100 kHz and 1 MHz), Helmholtz Coil Exposure
- IEC 61000-4-13, Conducted Susceptibility, Harmonics and Interharmonics (16 Hz to 2.4 kHz), Power Leads

- IEC 61000-4-16, Conducted Susceptibility, Common-Mode Disturbances (15 Hz to 150 kHz), Power and Signal Leads

All testing was performed with the TUT energized and operating under control of the executing TSAP software.

B. Test Levels

The following lists the EMI/RFI Testing emissions acceptance levels or applied susceptibility test levels from the applicable figures and tables of NRC RG 1.180, Rev. 1.

EMI/RFI Emissions Test Method	NRC RG 1.180, Rev. 1 Acceptance Level
MIL-STD-461E, CE101	Figure 3.1
MIL-STD-461E, CE102	Figure 3.2
MIL-STD-461E, RE101	Figure 3.3
MIL-STD-461E, RE102	Figure 3.4

EMI/RFI Susceptibility Test Method	NRC RG 1.180, Rev. 1 Test Level	
IEC 61000-4-3	Sect. 4.3.3:	10 V/m
IEC 61000-4-6	Sect. 4.1.2:	Power Leads, 140 dBμV
IEC 61000-4-6	Table 15:	Signal Leads, 130 dBμV
IEC 61000-4-8	Table 19:	Continuous, 30 A/m
IEC 61000-4-8	Table 19:	Short Duration, 300 A/m
IEC 61000-4-9	Table 19:	300 A/m
IEC 61000-4-10	Table 19:	30 A/m
IEC 61000-4-13	Table 10:	See Table 10
IEC 61000-4-16	Table 11:	Power Leads, See Table 11
	Table 11:	Signal Leads: 3/10 of Power Leads

C. Emissions Testing

The EMI/RFI emissions test results demonstrate that the Triconex TRICON v10 PLC does fully comply with the allowable emissions levels of NRC RG 1.180, Rev. 1 for MIL-STD-461E, RE101 and RE102 testing. The Triconex TRICON v10 PLC does not fully comply with the allowable emissions levels of NRC RG 1.180, Rev. 1 for MIL-STD-461E, CE101.

D. Susceptibility Testing

The EMI/RFI susceptibility test results show that the TRICON v10 PLC system complies with the minimum susceptibility levels required by NRC RG 1.180, Rev. 1, as presented in Tables 4-1 and 4-2. The main processors continued to function correctly throughout testing as noted. The transfer of input and output data was not interrupted. There were no interruptions or inconsistencies in the operation of the system or the software.

The TUT main processor, chassis power supply, remote extender, and communication modules fully comply with the minimum susceptibility thresholds required by NRC RG 1.180, Rev. 1 for all of the EMI/RFI susceptibility tests listed in Subsection A.

The EMI/RFI susceptibility test results show that the following TRICON v10 PLC input/output hardware does not fully comply with the minimum susceptibility thresholds required by NRC RG 1.180, Rev. 1 for the listed susceptibility tests:

<u>IEC 61000-4-3 Testing</u>

- RTD Signal Conditioning Module 1600083-600 (threshold levels determined)
- RTD Signal Conditioning Module 1600083-200 (threshold levels determined)
- RTD Signal Conditioning Module 1600024-030 (threshold levels determined)
- RTD Signal Conditioning Module 1600024-020 (threshold levels determined)

IEC 61000-4-6 Testing

- RTD Signal Conditioning Module 1600081-001 (no threshold levels determined)
- Digital Output Module 3601T (115 VAC) w/ ETP 9663-610N (threshold levels determined)

Prior to installing the TRICON v10 PLC in a nuclear safety-related application, an evaluation of the input, output and communication module susceptibilities should be performed. An evaluation of the module susceptibilities should also be performed for non-safety related applications if there is a potential for the PLC to impact plant reliability and availability. The TRICON v10 PLC EMI/RFI susceptibility testing documented in the EMI/RFI test report (Reference 6.14) provides the data required to perform such an evaluation.

Tables 4-1 and 4-2 included at the end of section 4.5 provide a summary of the EMI/RFI conducted and radiated susceptibility test results for each module installed in the TUT. The purpose of the table is to identify a set of modules which demonstrated acceptable susceptibility performance at the required NRC RG 1.180, Rev. 1 test levels.

The TRICON v10 PLC was tested without the benefit of a secondary enclosure, additional cable and wire shielding, or installed power line filtering. Mitigating actions to address the non-compliances in measured emission levels would likely incorporate these common in-plant installation features.

The specific TRICON v10 PLC hardware which was tested (chassis, power supplies, modules, external termination assemblies and interconnecting cabling) is identified in the Triconex Master Configuration List, Document No. 9600164-540 (Reference 6.20).

NOTE: The susceptibility test results given above are contingent on a TRICON v10 PLC installation design that separates and isolates the 24 VDC field power supplies to the discrete I/O and analog I/O module circuits.

TABLE 4-1: SUMMARY OF EMI/RFI CONDUCTED SUSCEPTIBILITY TEST RESULTS

Module Model No.	ETP Model No.	Module Type	IEC 61000-4-6 Radio Frequency 150 kHz - 80 MHz	IEC 61000-4-13 Harmonics and Interharmonics	IEC 61000-4-16 Common-Mode Disturbances
3008	- - -	Main Processor	Pass	Pass	Pass
8310	- - -	Power Supply, 115 VAC	Pass	Pass	Pass
8311	- - -	Power Supply, 230 VAC	Pass	Pass	Pass
8312	- - -	Power Supply, 24 VDC	Pass	Pass	Pass
4200	- - -	Remote Extender	Pass	Pass	Pass
4201	- - -	Remote Extender	Pass	Pass	Pass
4352A	- - -	Communication	Pass	Pass	Pass
3511	9794-110N	Pulse Input	Pass	Pass	Pass
3708E	9782-110N	Thermocouple Input	Pass	Pass	Pass
3501T	9561-810N	Digital Input, 115 VAC	Pass	Pass	Pass
	9561-110N	Digital Input, 115 VAC	Pass	Pass	Pass
3623T	9664-810N	Digital Output, 120 VDC	Pass	Pass	Pass
3603T	9664-810N	Digital Output, 120 VDC	Pass	Pass	Pass
3601T	9663-610N	Digital Output, 115 VAC	**Susceptible**	Pass	Pass
3503E	9563-810N	Digital Input, 24 VDC	Pass	Pass	Pass
3625	9662-810N	Digital Output, 24 VDC	Pass	Pass	Pass
	9662-610N	Digital Output, 24 VDC	Pass	Pass	Pass
3636T	9668-110N	Relay Output	Pass	Pass	Pass
3607E	9667-810N	Digital Output, 48 VDC	Pass	Pass	Pass
3502E	9562-810N	Digital Input, 48 VDC	Pass	Pass	Pass
3701	9795-610N	Analog Input, 0-10 VDC	Pass	Pass	Pass
	9783-110N	Analog Input, 0-10 VDC	Pass	Pass	Pass
3703E	9790-610N	Analog Input, 0-10 VDC	Pass	Pass	Pass
	9783-110N	Analog Input, 0-10 VDC	Pass	Pass	Pass
3805E	9860-610N	Analog Output, 4-20 mA	Pass	Pass	Pass

TABLE 4-1: SUMMARY OF EMI/RFI CONDUCTED SUSCEPTIBILITY TEST RESULTS

Module Model No.	ETP Model No.	Module Type	IEC 61000-4-6 Radio Frequency 150 kHz - 80 MHz	IEC 61000-4-13 Harmonics and Interharmonics	IEC 61000-4-16 Common-Mode Disturbances
3721	9764-310N	RTD, No. 1600083-600	Pass	Pass	Pass
		RTD, No. 1600083-200	Pass	Pass	Pass
		RTD, No. 1600024-040	Pass	Pass	Pass
		RTD, No. 1600024-030	Pass	Pass	Pass
		RTD, No. 1600024-020	Pass	Pass	Pass
		RTD, No. 1600024-010	Pass	Pass	Pass
		mV, No. 1600082-001	Pass	Pass	Pass
		RTD, No. 1600081-001	**Susceptible**	Pass	Pass
3721	9783-110N	Analog Input, 0-5 VDC	Pass	Pass	Pass
	9790-610N	Analog Input, 0-5 VDC	Pass	Pass	Pass
	9783-110N	Analog Input, 0-5 VDC	Pass	Pass	Pass

TABLE 4-2: SUMMARY OF EMI/RFI RADIATED SUSCEPTIBILITY TEST RESULTS

Module Model No.	ETP Model No.	Module Type	IEC 61000-4-3 High Frequency 26 MHz - 1 GHz	IEC 61000-4-8 60 Hz Magnetic Field	IEC 61000-4-9 Pulsed Magnetic Field	IEC 61000-4-10 Oscillatory Magnetic Field
3008	- - -	Main Processor	Pass	Pass	Pass	Pass
8310	- - -	Power Supply, 115 VAC	Pass	Pass	Pass	Pass
8311	- - -	Power Supply, 230 VAC	Pass	Pass	Pass	Pass
8312	- - -	Power Supply, 24 VDC	Pass	Pass	Pass	Pass
4200	- - -	Remote Extender	Pass	Pass	Pass	Pass
4201	- - -	Remote Extender	Pass	Pass	Pass	Pass
4352A	- - -	Communication	Pass	Pass	Pass	Pass
3511	9794-110N	Pulse Input	Pass	Pass	Pass	Pass

TABLE 4-2: SUMMARY OF EMI/RFI RADIATED SUSCEPTIBILITY TEST RESULTS

Module Model No.	ETP Model No.	Module Type	IEC 61000-4-3 High Frequency 26 MHz - 1 GHz	IEC 61000-4-8 60 Hz Magnetic Field	IEC 61000-4-9 Pulsed Magnetic Field	IEC 61000-4-10 Oscillatory Magnetic Field
3708E	9782-110N	Thermocouple Input	Pass	Pass	Pass	Pass
3501T	9561-810N	Digital Input, 115 VAC	Pass	Pass	Pass	Pass
	9561-110N	Digital Input, 115 VAC	Pass	Pass	Pass	Pass
3623T	9664-810N	Digital Output, 120 VDC	Pass	Pass	Pass	Pass
3603T	9664-810N	Digital Output, 120 VDC	Pass	Pass	Pass	Pass
3601T	9663-610N	Digital Output, 115 VAC	Pass	Pass	Pass	Pass
3503E	9563-810N	Digital Input, 24 VDC	Pass	Pass	Pass	Pass
3625	9662-810N	Digital Output, 24 VDC	Pass	Pass	Pass	Pass
3636T	9668-110N	Relay Output	Pass	Pass	Pass	Pass
3607E	9667-810N	Digital Output, 48 VDC	Pass	Pass	Pass	Pass
3502E	9562-810N	Digital Input, 48 VDC	Pass	Pass	Pass	Pass
3701	9795-610N	Analog Input, 0-10 VDC	Pass	Pass	Pass	Pass
	9783-110N	Analog Input, 0-10 VDC	Pass	Pass	Pass	Pass
3703E	9790-610N	Analog Input, 0-10 VDC	Pass	Pass	Pass	Pass
	9783-110N	Analog Input, 0-10 VDC	Pass	Pass	Pass	Pass
3805E	9860-610N	Analog Output, 4-20 mA	Pass	Pass	Pass	Pass
3721	9764-310N	RTD, No. 1600083-600	**Susceptible**	Pass	Pass	Pass
		RTD, No. 1600083-200	**Susceptible**	Pass	Pass	Pass
		RTD, No. 1600024-040	Pass	Pass	Pass	Pass
		RTD, No. 1600024-030	**Susceptible**	Pass	Pass	Pass
		RTD, No. 1600024-020	**Susceptible**	Pass	Pass	Pass
		RTD, No. 1600024-010	Pass	Pass	Pass	Pass
		mV, No. 1600082-001	Pass	Pass	Pass	Pass
		RTD, No. 1600081-001	Pass	Pass	Pass	Pass
3721	9783-110N	Analog Input, 0-5 VDC	Pass	Pass	Pass	Pass
	9790-610N	Analog Input, 0-5 VDC	Pass	Pass	Pass	Pass
	9783-110N	Analog Input, 0-5 VDC	Pass	Pass	Pass	Pass

4.6 Electrical Fast Transient Testing

EFT Testing of the TUT was performed in accordance with the applicable requirements of NRC Regulatory Guide 1.180, Rev. 1 and IEC 41000-4-4. The following EFT tests were performed (Reference 6.17):

- 120 VAC Chassis Power Supplies: ± 0.5 kV, ± 1.0 kV, ± 1.5 kV and ± 2.0 kV
- 230 VAC Chassis Power Supplies: ± 0.5 kV, ± 1.0 kV, ± 1.5 kV and ± 2.0 kV
- 24 VDC Chassis Power Supplies: ± 0.5 kV, ± 1.0 kV, ± 1.5 kV and ± 2.0 kV
- Peripheral Communications Cables: ± 0.5 kV and ± 1.0 kV
- ETP Input Power Wires: ± 0.5 kV and ± 1.0 kV
- Analog Input/Output Wires: ± 0.5 kV and ± 1.0 kV
- RTD, /T/C and Pulse Input Wires: ± 0.5 kV and ± 1.0 kV
- Discrete Input/Output Wires: ± 0.5 kV and ± 1.0 kV

A. The TUT met all applicable operational and performance requirements during and after each application of the EFT Test voltages.

B. The EFT Test results demonstrate that the Triconex Tricon v10 PLC will not experience operational failures or susceptibilities due to exposure to repetitive electrical fast transients on the power and signal input/output leads.

4.7 Surge Withstand Testing

Surge Withstand Testing of the TUT was performed in accordance with the applicable requirements of the IEC 61000-4-5 and IEC 61000-4-12 test methods. The following Surge Withstand tests were performed (Reference 6.15):

- IEC 61000-4-5 Combination Wave: ± 2.0 kV: Chassis Power Supplies
- IEC 61000-4-12 Ring Wave: ± 2.0 kV: Chassis Power Supplies
- IEC 61000-4-12 Ring Wave: ± 1.0 kV: Chassis Power Supplies
- IEC 61000-4-12 Ring Wave, IEC 61000-4-5 Combination Wave: ± 0.5 kV: AC Rated Discrete Input/Output Modules
- IEC 61000-4-12 Ring Wave, IEC 61000-4-5 Combination Wave: ± 1.0 kV: AC and DC Rated Discrete Input/Output Modules, Analog Input/Output Modules, TCM Communication Modules, MODBUS Serial Ports

A. The TUT met all applicable operational and performance requirements during and after each application of the Surge Withstand Test voltages.

B. The Surge Withstand Test results demonstrate that the Triconex TRICON v10 PLC will not experience operational failures or susceptibilities that could result in a loss of the ability to generate a trip due to exposure to Ring Wave and Combination Wave electrical surges to the components listed above.

4.8 Electrostatic Discharge (ESD) Testing

ESD Testing of the TUT was performed in accordance with the applicable requirements of Appendix B, Section 3.5 of EPRI TR-102323-R1 and IEC 61000-4-2. The following ESD tests were performed:

ESD Direct Contact Discharges: ± 2 kV, ± 4 kV, ± 6 kV and ± 8 kV
ESD Direct Air Discharges: ± 2 kV, ± 4 kV, ± 8 kV and ± 15 kV
ESD Indirect Contact Discharges: ± 2 kV, ± 4 kV, ± 6 kV and ± 8 kV

A. The TUT met all applicable operational and performance requirements during and after each application of the ESD Test voltages.

B. The ESD Test results demonstrate that the Triconex TRICON v10 PLC will not experience operational failures or susceptibilities due to exposure to electrostatic discharges. The main processors continued to function. The transfer of I/O was not interrupted. The TCM Peer-to-Peer and MODBUS communication links continued to operate correctly.

4.9 Isolation Testing

Class 1E to Non-1E isolation testing of the TRICON was performed in accordance with the requirements of EPRI TR-107330 and the guidance provided in IEEE Standard 384-1981. The testing demonstrated electrical isolation capability of Model 4352A TCM Communication Module and the Model 3636T Relay Output Module. Note that since interposing relays were required to monitor chassis alarm contacts, the chassis alarms are not qualified for electrical isolation.

A. The testing demonstrated electrical isolation capability of the TCM MODBUS serial communication ports to applied voltages of 250 VAC and 250 VDC (at 10 amps maximum) for 30 seconds.

B. The testing demonstrated electrical isolation capability of the relay output points to applied voltages of 600 VAC (at 25 amps maximum) and 250 VDC (at 10 amps maximum).

C. The fiber optic cables are incapable of transmitting electrical faults from the remote Non-1E RXM module to the primary RXM module (which would be installed in the safety related Tricon chassis), and therefore meet IEEE 384-1981 electrical isolation requirements.

4.10 Operability Testing

Operability testing involves exposing the TUT to various normal and abnormal conditions of input/output operation and source power. Operability Testing was performed in accordance with the requirements of Sections 5.3 and 6.4.3 of EPRI TR-107330, and the Invensys Triconex published specifications to ensure that performance data for the TUT were achieved during and after being subjected to the various qualification tests. The following specific tests were performed:

- Analog Input/Output Accuracy Test
- Response Time Test
- Discrete Input Test
- Discrete Output Test
- Timer Test
- Failover Test
- Loss of Power/Failure to Complete Scan Detection Test
- Power Interruption Test
- Power Quality Tolerance Test

The Operability Tests successfully established performance data for the TUT in accordance with the Invensys Triconex published specifications and/or EPRI TR-107330 specifications and all acceptance criteria stated in the procedure were met.

The test results Pre-Qualification Operability Test and Performance Proof Operability Test were analyzed to determine for degradation in the performance of the TUT. The analyses established that the TUT performed in accordance with Invensys Triconex published specifications and/or EPRI TR-107330 specifications before and, after Qualification Tests and no degradation in the performance of the TUT were identified.

5.0 MAINTENANCE

This section discusses requirements for long term maintenance of safety-related TRICON systems. These requirements are intended to identify important considerations for maintaining the environmental qualification of the TRICON system.

Specific maintenance considerations for the TRICON system include the following:

A. The TRICON PLC Main Chassis requires two batteries for RAM backup of the application programs. These batteries provide backup power to maintain system programming in the unlikely event of total loss of the two independent power sources and chassis power supplies. When powered, the TRICON will alarm when the battery power falls to a point where it can no longer support system operation. Based on the shelf life limitations of lithium batteries, new batteries should be installed when the battery life alarm occurs or every five years, whichever comes first.

B. The TRICON PLC power supplies contain electrolytic capacitors for filtering. These power supplies should be replaced on a ten year cycle.

6.0 REFERENCES

6.1 EPRI TR-107330, Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants

6.2 U.S. Nuclear Regulatory Commission Regulatory Guide 1.180, Revision 1, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems," October 2003

TRICONEX DOCUMENTS

6.3 Triconex Planning and Installation Guide, Part Number 9720051-005

6.4 Triconex User's Manual for Field Terminations, Part Number 9720052-004

6.5 Triconex Technical Product Guide, Part Number 9791007-004

6.6 Triconex TriStation 1131 Developer's Workbench User's Guide, Part Number 9720069-001

TRICONEX V10 NUCLEAR QUALIFICATION PROJECT DOCUMENTS

6.7 EQ Summary Report, Triconex Report Number 9600164-545

6.8 Software Qualification Report, Triconex Report Number 9600164-535

6.9 Failure Modes and Effects Analysis, Triconex Report Number 9600164-532

6.10 Reliability/Availability Study, Triconex Report Number 9600164-531

6.11 Tricon System Accuracy Specifications, Triconex Report Number 9600164-534

6.12 Seismic Test Report, Triconex Report Number 9600164-526

6.13 Environmental Test Report, Triconex Report Number 9600164-525

6.14 EMI/RFI Test Report, Triconex Report Number 9600164-527

6.15 Surge Withstand Test Report, Triconex Report Number 9600164-528

6.16 Class 1E to non-1E Isolation Test Report, Triconex Report Number 9600164-529

6.17 Electrical Fast Transient Test Report, Triconex Report Number 9600164-521

6.18 Performance Proof Test Report, Triconex Report Number 9600164-530

6.19 Radiation Test Report, Triconex Report Number 9600164-533

6.20 Master Configuration List, Triconex Report Number 9600164-540

6.21 Triconex Drawing No. 9600164-103, "Tricon v10 Nuclear Qualification Project System Block Diagram"

6.22 Triconex Drawing No. 9600164-102, "TRICON v10 Nuclear Qualification Project, Seismic Test Equipment Configuration Detail"

6.23 Triconex Drawing No. 9600164-100, "Tricon Under Test - General Arrangement"

6.24 Triconex Drawing No. 9600164-105, "Bill of Materials"

6.25 Triconex Drawing No.9600164-200, "Power Distribution Block Diagram"

6.26 Triconex Drawing No.9600164-201, "Power Distribution Wiring Diagram"

6.27 Triconex Drawing No.9600164-202, "Test Chassis #1 Power Distribution Wiring Diagram"

6.28 Triconex Drawing No.9600164-203, "Test Chassis #2 Power Distribution Wiring Diagram"

6.29 Triconex Drawing No.9600164-204, "Test Chassis #3 Power Distribution Wiring Diagram"

6.30 Triconex Drawing No.9600164-205, "Test Chassis #4 Power Distribution Wiring Diagram"

6.31 Triconex Drawing No.9600164-206, "Simulator Chassis #5 Power Dist. Wiring Diagram"

6.32 Triconex Drawing No. 9600164-207, "Simulator Chassis #6 Power Dist. Wiring Diagram"

6.33 Triconex Drawing No. 9600164-300, "Wiring Diagram General Notes"

6.34 Triconex Drawing No. 9600164-700, Wiring Schedule"

6.35 Triconex Document No. 9600164-800, "Supplemental Test Plan"

6.36 Unpublished International Electrotechnical Commission (IEC) committee draft Standard 61784-3/CD, "Industrial Process Measurement and Control – Digital Communications," May 2006