Project:	TRICON v10 NUCLEAR QUALIFICATION PROJECT

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SURGE WITHSTAND TEST REPORT

Document No: 9600164-528

Revision 1

April 30, 2008

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Document Change History			
Revision	**Date**	**Change**	**Preparer**
0	07/18/07	Initial Issue	M. Albers
1	04/30/08	Revised Reference 9.24 in response to NUPIC audit corrective action (Reference CAR 2528-1). Updated References 9.1 and 9.9 accordingly	F. Kloer

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1.0 EXECUTIVE SUMMARY

The TRICON v10 Nuclear Qualification Project Surge Withstand Test was performed on March 28 to April 13, 2007 at National Technical Systems (NTS) Laboratories in Boxborough, Massachusetts. As required by Triconex Document No. 9600164-500, "Master Test Plan," (Reference 9.1), the Surge Withstand Test was executed to demonstrate the withstand capability of the TRICON v10 Programmable Logic Controller (PLC) to electrical surges.

MPR Procedure No. 9600164-508, "Surge Withstand Test Procedure," (Reference 9.2) was developed in accordance with the requirements of the following documents:

- U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.180, Revision 1, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems," (Reference 9.3),
- EPRI TR-107330, "Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants," (Reference 9.4),
- International Electrotechnical Commission (IEC) Standard 61000-4-5, "Electromagnetic Compatibility (EMC), Part 4-5: Testing and Measurement Techniques, Surge Immunity Test," (Reference 9.5),
- IEC Standard 61000-4-12: Testing and Measurement Techniques, Oscillatory Waves Immunity Test," (Reference 9.6),
- Triconex Document No. 9600164-500, "Master Test Plan," (Reference 9.1), and,
- Triconex Document No. 9600164-002, "Nuclear Qualification Quality Plan," (Reference 9.7).

The procedure included steps to direct: 1) proper setup of the TRICON-Under-Test (TUT) and test system prior to testing, 2) application of electrical surges to the TUT components, 3) acquisition of TUT operational parameters during testing, and 4) evaluation of acceptable TUT performance during testing. The TUT executed a verified and validated Test Specimen Application Program (TSAP) throughout Surge Withstand Testing. The TSAP revision used was "V10_TSAP_REV_0". Surge Withstand Testing was performed by MPR certified Project Test Engineers and witnessed by Triconex Project Quality Assurance.

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The following Surge Withstand tests were performed:

IEC Standard 61000-4-5 Combination Wave: ± 2.0 kV (common mode and differential)

- 120 VAC and 230 VAC Chassis Power Supplies
- 24 VDC Chassis Power Supplies,

IEC Standard 61000-4-12 Ring Wave: ± 2.0 kV (common mode), ± 1.0 kV (differential)

- 120 VAC and 230 VAC Chassis Power Supplies,
- 24 VDC Chassis Power Supplies,

IEC Standard 61000-4-5 Combination Wave: ± 1.0 kV (common mode), ± 0.5 kV (diff.)

- AC and DC Rated Discrete Input Modules
- AC and DC Rated Discrete Output Modules
- Analog Input and Output Modules (RTD, T/C, Pulse, mV and mA)
- TCM Modules, MODBUS Serial Ports

IEC Standard 61000-4-12 Ring Wave: ± 1.0 kV (common mode), ± 0.5 kV (differential)

- AC and DC Rated Discrete Input Modules
- AC and DC Rated Discrete Output Modules
- Analog Input and Output Modules (RTD, T/C, Pulse, mV and mA)
- TCM Modules, MODBUS Serial Ports

The TUT performance was monitored throughout each applied Surge Withstand Test. The Surge Withstand Test results demonstrate that the Triconex TRICON v10 PLC will not experience operational failures or susceptibilities due to exposure to Ring Wave and Combination Wave

electrical surges to the components listed above. The specific TRICON v10 PLC hardware which was tested (chassis, power supplies, modules, external termination assemblies and interconnecting cabling) is identified in Triconex Document No. 9600164-540, "Master Configuration List," (Reference 9.9).

2.0 PURPOSE

The purpose of this test report is to summarize the results of Surge Withstand Testing of the TRICON v10 Nuclear Qualification Project TRICON-Under-Test (TUT) to meet the requirements of NRC Regulatory Guide 1.180 (Reference 9.3). The format of this test report conforms to Section 8.3.(4) of IEEE Standard 323-1974, "Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," (Reference 9.10).

Details regarding the performance and results of the Surge Withstand Testing are recorded in the completed MPR Procedure No. 9600164-508, "Surge Withstand Test Procedure," (Reference 9.11). Conclusions from the Surge Withstand Testing are provided in Section 8.0 of this test report.

3.0 TEST OBJECTIVE

NRC RG 1.180 (Reference 9.3) states that Electromagnetic Interference / Radiofrequency Interference (EMI/RFI) Testing (including Surge Withstand Testing) is required to demonstrate compliance with NRC regulations on testing to address the effects of EMI/RFI and power surges on safety-related instrumentation and control systems. Appendix 8 of Triconex Document No. 9600164-500 (Reference 9.1) states that Surge Withstand Testing is conducted to demonstrate the surge withstand capability of the TUT as required in NRC RG 1.180. MPR Procedure No. 9600164-508 (Reference 9.2) states that Surge Withstand Testing demonstrates the suitability of the TRICON v10 PLC for qualification as a safety-related, Class 1E device with respect to immunity to AC power and signal input/output line electrical surges.

4.0 DESCRIPTION OF TEST SPECIMEN

The equipment tested consists of four TRICON v10 PLC chassis populated with selected main processor, input, output, communication, chassis interface and chassis power supply modules. The tested equipment also includes external termination panels (ETPs) provided for connection of field wiring to the TRICON v10 input and output modules, and interfacing cable assemblies for connection of the ETPs to the TRICON v10 chassis and for interconnection of the TRICON v10 chassis.

Triconex Drawing No. 9600164-100 (Reference 9.8), shows the basic configuration of the TUT components for Surge Withstand Testing. Triconex Drawing No. 9600164-103, "TRICON v10 Nuclear Qualification Project System Block Diagram," (Reference 9.12), shows the general arrangement and interconnection of the TUT chassis. Triconex Document No. 9600164-541, "TRICON v10 Nuclear Qualification Project, System Description," (Reference 9.13), provides an

overview and description of the TUT and test system. A detailed identification of the tested equipment is provided in Triconex Document No. 9600164-540 (Reference 9.9).

During testing, the TUT was executing a Test Specimen Application Program (the TSAP) developed specifically for the qualification project and designed to support the test procedures, which demonstrate the functionality of the TUT during all phases of qualification testing. Requirements for operation of the TSAP are defined in Triconex Document No. 9600164-517, "Test Specimen Application Program (TSAP) Software Requirements Specification (SRS)," (Reference 9.14). The completed MPR Procedure No. 9600164-508 (Reference 9.11) identifies the TSAP revision used during this testing as "V10_TSAP_REV_0". Triconex Document No. 9600164-540 (Reference 9.9) identifies the revision level of all TUT firmware.

5.0 TEST SETUP AND INSTRUMENTATION

The following sections describe the setup of the TUT during Surge Withstand Testing, the instrumentation used to generate and measure the applied Surge Withstand test conditions, and the instrumentation used to measure TUT performance during and after testing. The TUT setup is documented in the completed MPR Procedure No. 9600164-508 (Reference 9.11). Specifications for test instrumentation supplied by NTS Laboratories are included in NTS Test Procedure No. TP62987-07N-EMI, "Test Procedure for EMI/RFI Testing of the TRICON v10 Nuclear Qualification Project TRICON-Under-Test," (Reference 9.15).

5.1 TRICON-Under-Test Mounting

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The mounting and grounding configuration described above meets the requirements of Section 7, "Test Set-up" of IEC Standard 61000-4-5 (Reference 9.5) and IEC Standard 61000-4-12 (Reference 9.6), which specify the test set-up for type tests performed in laboratories.

5.2 TRICON-Under-Test Chassis and Module Configuration

Section 4.0 above describes the general arrangement of the TUT which was maintained throughout all of the qualification testing. Chassis configurations for Surge Withstand Testing are documented in Triconex Document No. 9600164-540 (Reference 9.9).

5.3 TRICON-Under-Test Power Supply and Wiring Configuration

NRC RG 1.180 (Reference 9.3) does not include specific requirements for configuration of equipment power supplies or wiring during Surge Withstand Testing. Section 7, "Test Set-up" of IEC Standard 61000-4-5 (Reference 9.5) and IEC Standard 61000-4-12 (Reference 9.6) specify that the equipment-under-test shall be in the manufacturer's recommended configuration and operating conditions.

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5.4 NTS Instrumentation

NTS provided the test instrumentation for generating, applying, and monitoring the electrical surge test signals. NTS also provided instrumentation for measuring temperature and relative humidity inside the anechoic test chamber during Surge Withstand Testing. These instruments are identified in NTS Test Report No. TR62987-07N-EMI (Reference 9.24).

5.5 Triconex and MPR Instrumentation

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5.6 Instrument Calibration

All tests were performed using calibrated test instruments. Calibration certifications are held by NTS, MPR and Triconex. NTS Test Report No. TR62987-07N-EMI (Reference 9.24) documents the calibration status of the test instrumentation used by NTS. The completed MPR Procedure No. 9600164-508 (Reference 9.11) documents the calibration status of the test instrumentation used by MPR. The completed Triconex Procedure No. 9600164-502 (Reference 9.26) documents the calibration status of the test instrumentation used by Triconex.

6.0 TEST PROCEDURES

Surge Withstand Testing of the TUT was performed to the requirements of Sections 4 and 5 of NRC RG 1.180 (Reference 9.3). Section 4 of NRC RG 1.180 addresses Surge Withstand Testing of signal leads and endorses both Department of Defense (DoD) Military Standard and IEC Standard Surge Withstand Test methods. The qualifier has the option to use either series of test methods. Surge Withstand Testing of the TUT signal leads was performed according to IEC Standard 61000-4-5 (Reference 9.5) and IEC Standard 61000-4-12 (Reference 9.6). Section 5 of NRC RG 1.180 addresses Surge Withstand Testing of power leads and endorses both Institute of Electrical and Electronics Engineers (IEEE) and IEC Standard Surge Withstand Test methods. The qualifier has the option to use either series of test methods. Surge Withstand Testing of the TUT AC power supplies was performed according to IEC Standard 61000-4-5 and IEC Standard 61000-4-12.

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The following sections describe the approach to satisfying the requirements of RG 1.180 (Reference 9.3), IEC Standard 61000-4-5 (Reference 9.5) and IEC Standard 61000-4-12 (Reference 9.6) for Surge Withstand Testing of the TUT.

6.1 Test Sequence

Figure 2 of Triconex Document No. 9600164-500 (Reference 9.1) shows the sequence of qualification testing performed on the TUT. In accordance with the test sequence shown in Figure 2, Surge Withstand Testing was performed after Radiation Exposure, Environmental, Seismic, EMI/RFI and Electrical Fast Transient Testing, and prior to Electrostatic Discharge and Class 1E to Non-1E Isolation Testing.

6.2 Test Method

Section 5 of NRC RG 1.180 (Reference 9.3) includes the requirements for Surge Withstand Testing of the AC power supplies of safety-related instrumentation and control (I&C) systems. Section 5 endorses both IEEE Standard and IEC Standard Surge Withstand test methods. The qualifier has the option to use either series of test methods. Surge Withstand Testing of the TUT AC power supplies was performed according to IEC Standard 61000-4-5 (Reference 9.5) and IEC Standard 61000-4-12 (Reference 9.6).

Section 4.2 of NRC RG 1.180 includes the requirements for Surge Withstand Testing of the signal leads of safety-related instrumentation and control (I&C) systems. Section 4.2 endorses both DoD Military Standard and IEC Standard Surge Withstand test methods. The qualifier has the option to use either series of test methods. Surge Withstand Testing of the TUT signal leads was performed according to IEC Standard 61000-4-5 (Reference 9.5) and IEC Standard 61000-4-12 (Reference 9.6).

6.3 Test Levels

Table 22 of NRC RG 1.180 (Reference 9.3) defines the IEC Standard 61000-4-12 Ring Wave and IEC Standard 61000-4-5 Combination Wave surge withstand levels for the power supplies of safety related instrumentation installed in various plant locations. Based on the discussion in Section 5 of NRC RG 1.180, the power supplies of a TRICON v10 system are expected to be installed in *Category B* locations with surge waveform *Low Exposure* levels. The corresponding Ring Wave surge withstand level is 2 kV and the corresponding Combination Wave surge withstand level is 2 kV open circuit and 1 kA short circuit. Table 1 of IEC Standard 61000-4-12 and Table A.1 of IEC Standard 61000-4-5 specify that the surge test voltage level can be reduced by one-half when the surge is applied in differential (line to line) mode vs. common (line/neutral to ground) mode. For Combination Wave tests of the TUT power supplies, the differential mode surge voltages were conservatively applied at the full test level. For Ring Wave tests of the TUT power supplies, the differential mode surge voltages were applied at one-half the full test level as specified by the test standard.

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Table 15 of NRC RG 1.180 defines the IEC Standard 61000-4-12 Ring Wave and IEC Standard 61000-4-5 Combination Wave surge withstand levels for the signal leads of safety related instrumentation installed in various plant locations. Based on the discussion in Section 4.2 of NRC RG 1.180, Rev. 1, the signal circuits of a TRICON v10 system are expected to be installed in *Low Exposure* locations with *Level 2* surge waveforms. The corresponding Ring Wave surge withstand level is 1 kV and the corresponding Combination Wave surge withstand level is 1 kV open circuit and 0.5 kA short circuit. For tests of the TUT signal leads, the differential mode surge voltages were applied at one-half the full test level as allowed by the test standards.

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In accordance with IEC Standard 61000-4-5 (Reference 9.5) and IEC Standard 61000-4-12 (Reference 9.6), as supplemented by Section 4.6.2 of EPRI TR-107330 (Reference 9.4), Combination Wave and Ring Wave Surge Withstand Testing was performed on the following input/output and communication port test points.

- From the line (L) side to the neutral (N) side of one point of each AC rated discrete input module (0.5 kV).
- From the low (N or -) side to AC ground of one point of each AC and DC rated discrete input module (1.0 kV).
- From the line (L) side to the neutral (N) side of one point of each AC rated discrete and relay output module, with the point in both the ON and OFF states (0.5 kV).
- From the low (N or -) side to AC ground of one point of each AC and DC rated discrete and relay output module, with the point in both the ON and OFF states (1.0 kV).
- From the shield connection to AC ground of one point of each analog, pulse and RTD input module (1.0 kV).
- From the shield connection to AC ground of each connected point of the T/C input module (1.0 kV).

- From the shield connection to AC ground of one point of each analog output module (1.0 kV).

- From the shield connection to AC ground of the Serial 2 port of a TCM Module (1.0 kV).

EPRI TR-107330, Section 4.6.2, Items G and K also required that Surge Withstand Testing be performed on the following input/output signal and data communication connections:

- Between the common connections of any discrete inputs and outputs where a common connection is shared by two or more I/O points. This configuration is not applicable to the input/output modules installed in the TUT.

- Between the power supply AC ground and the transmit and receive signal common pins on any PLC communication port if the signal common pin is different from the signal ground pin. This requirement does not apply to the TCM Module Serial 1 communication port.

EPRI TR-107330, Section 4.3.4.3, Item E requires Surge Withstand Testing of any devices required for connecting the main PLC chassis to other types of chassis.

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Section 6.3.5 of EPRI TR-107330 (Reference 9.4) states that Surge Withstand Testing should be performed on a representative sample of points for each type of input/output module.

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Section 5 of IEC Standard 61000-4-5 states that all voltages of the lower tests levels shall be satisfied (i.e., the surge voltage should be applied as a series of steps from a lower range value up to the maximum required test value).

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6.4 TRICON-Under-Test Operation

Section 7, "Test Set-up" of IEC Standard 61000-4-5 (Reference 9.5) and IEC Standard 61000-4-12 (Reference 9.6) specify that the equipment-under-test shall be in the manufacturer's recommended configuration and operating conditions.

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6.5 TRICON-Under-Test Performance Monitoring

Appendix 8 of Triconex Document No. 9600164-500 (Reference 9.1) and Section 6.6 of this test report list the Surge Withstand Test acceptance criteria. Appendix 8 states that monitoring of normal TUT operation during Surge Withstand Testing will demonstrate satisfaction of the acceptance criteria. To clarify the definition of normal operation, the following additional acceptance criteria adapted from Section 4.3.7 of EPRI TR-107330 (Reference 9.4) were applied during Surge Withstand Testing:

i.) The main processors shall continue to function.
ii.) The transfer of I/O data shall not be (permanently) interrupted.
iii.) The applied electrical surge disturbances shall not cause the discrete I/O to (permanently) change state.
iv.) Analog I/O levels shall not (permanently) vary more than 3% (of full scale).

During Surge Withstand Testing, NTS Laboratories was responsible for generating and exposing the test system to the required levels of electrical surge disturbances given in Sections 4.2 and 5 of NRC RG 1.180 (Reference 9.3). During Surge Withstand Testing, MPR and Triconex were responsible for monitoring operation of the test system and determining the susceptibility of the TUT to the applied levels of electrical surge disturbances.

6.6 Test Acceptance Criteria

The following Surge Withstand Test acceptance criteria are as given in Appendix 8 of Triconex Document No. 9600164-500 (Reference 9.1), and Section 4.6.2 of EPRI TR-107330 (Reference 9.4).

(a) Application of the surge test voltages specified in Tables 15 and 22 of NRC RG 1.180 (Reference 9.3) to the specified TUT test points shall not damage any other module or device in the TUT, or cause disruption of the operation of the TUT backplane signals or any other data acquisition signals that could result in a loss of the ability to generate a trip.

(b) The TUT shall operate as intended during and after application of the surge test voltages. Evaluation of normal operating performance data (inputs, outputs and diagnostic indicators)

shall demonstrate operation as intended, including the following specific operational performance from Section 4.3.7 of EPRI TR-107330 (Reference 9.4):

i.) The main processors shall continue to function.
ii.) The transfer of I/O data shall not be (permanently) interrupted.
iii.) The applied surge test voltages shall not cause the discrete I/O to (permanently) change state.
iv.) Analog I/O levels shall not (permanently) vary more than 3% (of full scale).

(c) Per Section 6.3.5 of TR-107330 (Reference 9.4), failures of one or more redundant devices are acceptable so long as the failures do not result in the inability of the TUT to operate as intended.

7.0 TEST RESULTS

This section summarizes the results of Surge Withstand Testing of the TUT. This section also discusses performance or data anomalies which were observed or recorded during the testing.

7.1 Surge Withstand Test Setup and Checkout Testing

Triconex Procedure No. 9600164-502, "System Setup and Checkout Procedure," (Reference 9.28) directs setup of the TUT for the different qualification tests to be performed, and verifies proper operation of the TUT and test system prior to start of testing. Surge Withstand Testing of the TUT was performed following EMI/RFI Testing. The configuration of the test system for Surge Withstand Testing remained the same as that for EMI/RFI Testing, as documented in Reference 9.26. Therefore, the System Setup and Checkout Procedure was not required to be performed prior to start of Surge Withstand Testing.

7.2 Surge Withstand Testing

Surge Withstand Testing of the TUT was performed in accordance with MPR Procedure No. 9600164-508 (Reference 9.2), and NTS Test Procedure No. TP62987-07N-EMI (Reference 9.15). All testing was performed with the TUT energized and operating under control of the executing TSAP software. The following Surge Withstand Tests were performed to the IEC Standard 61000-4-5 and IEC Standard 61000-4-12 test methods (References 9.5 and 9.6):

- IEC 61000-4-12 Ring Wave Test, 1.0 kV and 2.0 kV: Chassis Power Supplies
- IEC 61000-4-5 Combination Wave Test, 2.0 kV: Chassis Power Supplies
- IEC 61000-4-12 Ring Wave Test, 0.5 and 1.0 kV: Discrete Input/Output Modules
- IEC 61000-4-5 Combination Wave Test, 0.5 and 1.0 kV: Discrete Input/Output Modules
- IEC 61000-4-12 Ring Wave Test, 1.0 kV: Analog Input/Output Modules

- IEC 61000-4-5 Combination Wave Test, 1.0 kV: Analog Input/Output Modules
- IEC 61000-4-12 Ring Wave Test, 1.0 kV: Communication Modules
- IEC 61000-4-5 Combination Wave Test, 1.0 kV: Communication Modules

7.3 Chassis Power Supply Ring Wave Testing

Ring Wave Surge Withstand Testing of the chassis power supplies was performed as described in IEC Standard 61000-4-12 (Reference 9.6) and Section 5 of NRC RG 1.180 (Reference 9.3). Each of the TUT 120 VAC, 230 VAC and 24 VDC chassis power supply circuits was individually subjected to 2.0 kV peak common mode or 1.0 kV peak differential mode, 0.5 microsecond rise time, 100 kHz ring wave pulses at a minimum repetition rate of one pulse per second applied for a minimum 60 second time period. The pulses were applied across the following power supply input leads:

120 VAC and 230 VAC Chassis Power Supplies

- Line to Neutral, 1.0 kV peak
- Line to AC Ground, 2.0 kV peak
- Neutral to AC Ground, 2.0 kV peak
- Line/Neutral to AC Ground, 2.0 kV peak

24 VDC Chassis Power Supplies

- High (DC Positive) to Low (DC Negative), 1.0 kV peak
- Low (DC Negative) to AC Ground, 2.0 kV peak

Five positive and five negative surges were applied across each lead combination at each phase angle of 0, 90 and 270 degrees with respect to the AC power crossover point. The surges were shunt coupled to the power leads via a surge coupling capacitor network.

7.4 Chassis Power Supply Combination Wave Testing

Combination Wave Surge Withstand Testing of the chassis power supplies was performed as described in IEC Standard 61000-4-5 (Reference 9.5) and Section 5 of NRC RG 1.180 (Reference 9.3). Each of the TUT 120 VAC, 230 VAC and 24 VDC chassis power supplies was individually subjected to 2.0 kV peak combination wave surges with an open-circuit voltage waveform of 1.2 microsecond rise time and 50 microsecond duration and a short-circuit current waveform of 8 microsecond rise time and 20 microsecond duration. The surges were applied across the following power supply input leads:

120 VAC and 230 VAC Chassis Power Supplies

- Line to Neutral, 2.0 kV peak
- Line to AC Ground, 2.0 kV peak
- Neutral to AC Ground, 2.0 kV peak
- Line/Neutral to AC Ground, 2.0 kV peak

24 VDC Chassis Power Supplies

- High (DC Positive) to Low (DC Negative), 2.0 kV peak
- Low (DC Negative) to AC Ground, 2.0 kV peak

Five positive and five negative surges (phase synchronized to the AC line voltage) were applied across each lead combination at a minimum interval time of 60 seconds. The surges were shunt coupled to the power leads via a surge coupling capacitor network.

7.5 Input/Output Signal and Data Communication Module Ring Wave Testing

Ring Wave Surge Withstand Testing of the TUT input/output signal and data communication modules was performed as described in IEC Standard 61000-4-12 (Reference 9.6) and NRC RG 1.180 (Reference 9.3), as supplemented by Section 4.6.2 of EPRI TR-107330 (Reference 9.4). A representative number of points on each of these modules were subjected to 1.0 kV peak common mode or 0.5 kV peak differential mode, 0.5 microsecond rise time, 100 kHz ring wave pulses at a minimum repetition rate of one pulse per second applied for a minimum 60 second time period. The pulses were applied across the following circuit points:

AC Rated Discrete Input, Discrete Output and Relay Output Modules

- AC Line to AC Common (Neutral), 0.5 kV peak

AC and DC Rated Discrete Input, Discrete Output and Relay Output Modules

- AC Common (Neutral) to AC Ground, 1.0 kV peak
- DC Low (Negative) to AC Ground, 1.0 kV peak

All Analog, Pulse, Thermocouple and RTD Input and Analog Output Modules

- Shield Connection to AC Ground, 1.0 kV peak

Communication Modules

- Serial Communication Port Shield Connection to AC Ground, 1.0 kV peak

Five positive and five negative surges were applied across each circuit point at each phase angle of 0, 90 and 270 degrees with respect to the AC power crossover point. All discrete input, discrete output and relay output points were tested in both the ON and OFF states.

7.6 Input/Output Signal and Data Communication Module Combination Wave Testing

Combination wave Surge Withstand Testing of the TUT input/output signal and data communication modules was performed as described in IEC Standard 61000-4-5 (Reference 9.5) and NRC RG 1.180 (Reference 9.3), as supplemented by Section 4.6.2 of EPRI TR-107330 (Reference 9.4). A representative number of points on each of these modules were subjected to 1.0 kV peak common mode or 0.5 kV peak differential mode combination wave surges with an open-circuit voltage waveform having a 1.2 microsecond rise time and 50 microsecond duration and a short-circuit current waveform having an 8 microsecond rise time and 20 microsecond duration. The pulses were applied across the following circuit points:

AC Rated Discrete Input, Discrete Output and Relay Output Modules

- AC Line to AC Common (Neutral), 0.5 kV peak

AC and DC Rated Discrete Input, Discrete Output and Relay Output Modules

- AC Common (Neutral) to AC Ground, 1.0 kV peak
- DC Low (Negative) to AC Ground, 1.0 kV peak

All Analog, Pulse, Thermocouple and RTD Input and Analog Output Modules

- Shield Connection to AC Ground, 1.0 kV peak

Communication Modules

- Serial Communication Port Shield Connection to AC Ground, 1.0 kV peak

Five positive and five negative surges (phase synchronized to the AC line voltage) were applied across each circuit point at a minimum interval time of 60 seconds. All discrete input, discrete output and relay output points were tested in both the ON and OFF states.

7.7 TRICON-Under-Test Performance Monitoring

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Data sheets included in the completed MPR Procedure No. 9600164-508 (Reference 9.11) provide a detailed listing of the TUT input, output and peripheral communication points that were monitored during Surge Withstand Testing, and document the results of analysis of the monitored operational data. Attachment 1 of this test report includes a set of figures showing the normal operation of the data points which were monitored.

The data analysis shows that the TUT continued to operate in accordance with the test acceptance criteria given in Section 6.6 of this test report during and after application of the surge test voltages. Specifically:

a) Application of the surge test voltages to the chassis power supply modules did not result in damage to the tested power supply modules or any other modules installed in the TUT, including the main processor modules, the RXMs, the input/output modules or the communication modules.

b) Application of the surge test voltages to the chassis power supply modules did not result in disruption of the operation of the TUT, including the ability to correctly acquire input signals and generate output signals.

c) Application of the surge test voltages to the input/output module points did not result in damage to the tested input/output modules or any other modules installed in the TUT, including the main processor modules, the power supply modules, the RXMs, other input/output modules and the communication modules.

d) Application of the surge test voltages to the input/output module points did not result in permanent disruption of the operation of the TUT, including the ability to correctly acquire the input signals associated with any other input module points, and to generate the output signals associated with any other output module points.

e) Application of the surge test voltages to the communication module ports did not result in damage to the tested communication modules or any other modules installed in the TUT, including the main processor modules, the power supply modules, the RXMs, the input/output modules and other communication modules.

f) Application of the surge test voltages to the communication module ports did not result in disruption of the operation of the TUT, including the ability to correctly receive input signals from other communication module ports, and to transmit output signals to other communication module ports.

g) Evaluation of TUT normal operating data (inputs, outputs and diagnostic indicators) during and after each Surge Withstand Test demonstrated operation as intended, including the following specific operational performance adapted from Section 4.3.7 of EPRI TR-107330 (Reference 9.4):

i.) The main processors continued to function.
ii.) The transfer of I/O data was not (permanently) interrupted.
iii.) The applied electrical surges did not cause the discrete I/O to (permanently) change state.
iv.) Analog I/O levels did not (permanently) vary more than 3% (of full scale).

Per Section 6.6, disruptions in the operation of the TUT data acquisition signals (inputs and outputs) are acceptable if they do not result in a loss of the ability to generate a trip. In general, this statement is interpreted to imply that momentary (non-permanent) disruptions in the normal operation of the input/output circuits are acceptable as these would not necessarily disable the trip function of a specific TRICON v10 application. However, each such disruption encountered during testing was evaluated in detail to assess the applicability of this interpretation of the EPRI TR-107330 acceptance criteria. These evaluations are discussed in Section 7.9 below.

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8.0 CONCLUSIONS

1. Surge Withstand Testing of the TUT was performed in accordance with the applicable requirements of NRC RG 1.180 (Reference 9.3), IEC Standard 61000-4-5 (Reference 9.5), and IEC Standard 61000-4-12 (Reference 9.6). The following Surge Withstand tests were performed:

   IEC Standard 61000-4-5 Combination Wave: ± 2.0 kV

   - 120 VAC and 230 VAC Chassis Power Supplies,
     - Line to Neutral
     - Line to AC Ground
     - Neutral to AC Ground
     - Line and Neutral to AC Ground

   - 24 VDC Chassis Power Supplies,
     - High Side (+) to Low Side (-)
     - Low Side (-) to AC Ground

   IEC Standard 61000-4-12 Ring Wave: ± 2.0 kV

   - 120 VAC and 230 VAC Chassis Power Supplies,
     - Line to AC Ground
     - Neutral to AC Ground
     - Line and Neutral to AC Ground

   - 24 VDC Chassis Power Supplies,
     - Low Side (-) to AC Ground

   IEC Standard 61000-4-12 Ring Wave: ± 1.0 kV

   - 120 VAC and 230 VAC Chassis Power Supplies,
     - Line to Neutral

   - 24 VDC Chassis Power Supplies,
     - High Side (+) to Low Side (-)

IEC Standard 61000-4-12 Ring Wave, IEC 61000-4-5 Combination Wave: ± 0.5 kV

- AC Rated Discrete Input Modules
  - One Point per Module
  - Line to Neutral
  - Point ON and OFF

- AC Rated Discrete Output Modules
  - One Point per Module
  - Line to Neutral
  - Point ON and OFF

IEC 61000-4-12 Ring Wave, IEC 61000-4-5 Combination Wave: ± 1.0 kV

- AC Rated Discrete Input and Output Modules
  - One Point per Module
  - Neutral to AC Ground
  - Point ON and OFF

- DC Rated Discrete Input and Output Modules
  - One Point per Module
  - Low Side (-) to AC Ground
  - Point ON and OFF

- Analog Input and Output Modules (RTD, T/C, Pulse, mV and mA)
  - One Point per Module
  - Shield to AC Ground

- TRICON Communication Modules (TCMs), MODBUS Serial Ports
  - One Port
  - Connector Shield to AC Ground

2. The TUT met the Test Acceptance Criteria given in Section 6.6 of this test report. Specifically, during Surge Withstand Testing:

   (a) Applying the surge test voltages to the specified TUT test points did not damage any other module or device in the TUT, or cause disruption of the operation of the TUT backplane signals or any other data acquisition signals that could result in a loss of the ability to generate a trip.

(b) Evaluation of normal operating data showed that the TUT operated as intended during and after exposure to the surge test voltages. Specifically, in accordance with Section 4.3.7 of EPRI TR-107330 (Reference 9.4):

i.) The main processors continued to function.
ii.) The transfer of I/O data was not permanently interrupted.
iii.) The applied surge test voltages did not cause the discrete I/O to permanently change state.
iv.) Analog I/O levels did not permanently vary more than 3% (of full scale).

3. 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. The specific TRICON v10 PLC hardware which was tested (chassis, power supplies, modules, external termination assemblies and interconnecting cabling) is identified in Triconex Document No. 9600164-540 (Reference 9.9).

9.0 REFERENCES

Note: Triconex qualification project documentation and hardware is configuration controlled under the Triconex Quality Assurance Program. Triconex Document No. 9600164-540, "Master Configuration List," (Reference 9.9) provides a record of the currently applicable revision level of all Triconex documents, procedures and drawings throughout performance of the qualification program. As recorded in the completed MPR Procedure No. 9600164-508 (Reference 9.11), Triconex Document No. 9600164-540, Rev. 14 was in effect at the start of Surge Withstand Testing.

9.1 Triconex Document No. 9600164-500, "Master Test Plan," Rev. **5**

9.2 MPR Procedure No. 9600164-508, "Surge Withstand Test Procedure," Rev. 1

9.3 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

9.4 EPRI TR-107330, "Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants," Final Report dated December, 1996

9.5 IEC Standard 61000-4-5, "Electromagnetic Compatibility (EMC), Part 4-5: Testing and Measurement Techniques, Surge Immunity Test," April 2001

9.6 IEC Standard 61000-4-12, "Electromagnetic Compatibility (EMC), Part 4-12: Testing and Measurement Techniques, Oscillatory Waves Immunity Test," April 2001

9.7 Triconex Document No. 9600164-002, "Nuclear Qualification Quality Plan," Rev. 3

9.8 Triconex Drawing No. 9600164-100, "TRICON v10 Nuclear Qualification Project TRICON Under Test - General Arrangement," Rev. 1

9.9 Triconex Document No. 9600164-540, "Master Configuration List," Rev. 21

9.10 IEEE Standard 323-1974, "Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations"

9.11 Completed MPR Procedure No. 9600164-508, "Surge Withstand Test Procedure," Rev. 1, MPR Review and Approval Dated July 18, 2007

9.12 Triconex Drawing No. 9600164-103, "TRICON v10 Nuclear Qualification Project System Block Diagram," Rev. 2

9.13 Triconex Document No. 9600164-541, "TRICON v10 Nuclear Qualification Project, System Description," Rev. 0

9.14 Triconex Document No. 9600164-517, "Test Specimen Application Program (TSAP) Software Requirements Specification (SRS)," Rev. 3

9.15 National Technical Systems Test Procedure No. TP62987-07N-EMI, "Test Procedure for Electromagnetic Compatibility Qualification of the TRICON v10 Nuclear Qualification Project TRICON-Under-Test," Rev. 0

9.16 Triconex Drawing No. 9600164-201, Sheets 1 and 2, "TRICON v10 Nuclear Qualification Project - Power Distribution Wiring Diagram," Rev. 1

9.17 Triconex Drawing No. 9600164-202, Sheet 1, "TRICON v10 Nuclear Qualification Project - Test Chassis #1 Power Distribution Wiring Diagram," Rev. 0

9.18 Triconex Drawing No. 9600164-203, Sheets 1 and 2, "TRICON v10 Nuclear Qualification Project - Test Chassis #2 Power Distribution Wiring Diagram," Rev. 0

9.19 Triconex Drawing No. 9600164-204, Sheets 1 and 2, "TRICON v10 Nuclear Qualification Project - Test Chassis #3 Power Distribution Wiring Diagram," Rev. 0

9.20 Triconex Drawing No. 9600164-205, Sheets 1 and 2, "TRICON v10 Nuclear Qualification Project - Test Chassis #4 Power Distribution Wiring Diagram," Rev. 2

9.21 Triconex Drawing No. 9600164-206, Sheet 1, "TRICON v10 Nuclear Qualification Project - Simulator Chassis #5 Power Distribution Wiring Diagram," Rev. 0

9.22 Triconex Drawing No. 9600164-207, Sheet 1, "TRICON v10 Nuclear Qualification Project - Simulator Chassis #6 Power Distribution Wiring Diagram," Rev. 0

9.23 Completed MPR Procedure No. 9600164-510, "EMI/RFI Test Procedure," Rev. 0, MPR Review and Approval Dated July 16, 2007

9.24 National Technical Systems Test Report No. TR62987-07N-EMI, "Test Report for Electromagnetic Compatibility Qualification of the TRICON v10 Nuclear Qualification Project TRICON-Under-Test," Rev. **1**

9.25 Triconex Document No. 9600164-700, "TRICON v10 Nuclear Qualification Project Wiring Schedule," Rev. 3

9.26 Completed Pre-EMI/RFI Testing Run No. 3.6 of Triconex Procedure No. 9600164-502, "System Setup and Checkout Procedure," Rev. 4

9.27 MPR Document No. 0449-0602-PRS-001, Rev. 1, "Procurement Specification for National Technical Systems Qualification Testing Services," March 14, 2007

9.28 Triconex Procedure No. 9600164-502, "System Setup and Checkout Procedure," Rev. 4

9.29 MPR Document No. 0449-0602-QAP-01, "Quality Assurance Plan for Triconex Corporation TRICON v10 PLC Nuclear Qualification Project," Revision 0 dated May 12, 2006.

10.0 ATTACHMENTS

Attachment 1: Example Plots of TUT Normal Operating Data

ATTACHMENT 1

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