NSRP | National Shipbuilding Research Program

Shore Power Connector Tester

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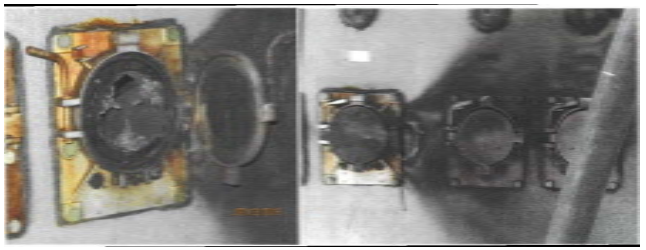
Remotely Held

Project Overview

- A Dec. 2014 NSWCCD-SSES report notes a significant number of 450V 400A surface ship shore power connection plug and receptacle failures.
- These connectors are subject to corrosion at the connection pins themselves. Corrosion leads to high impedance contact and subsequent heating of the pins and eventual failure.
- The connectors are tested before connection to shore power with a MegOhm meter ("Megger") to verify that there are no accidental low impedance paths between the phases or to ground.
- In Feb. 2018, a pin failure in a 450V shore power connector on a DDG-51 class destroyer led to an Arc Flash Event in which the connector exploded.
- Due to similar issues in the fleet, a new Maintenance Requirement Card (MRC) has been issued that requires Megger testing from each pin in the receptacle to every other pin and also to ground, rather than just a single phase to phase and phase to ground tests.



(a)

(b)

Fig. 1 (a) Results of an arc flash event at 450 V Shore Power Connector on destroyer
(b) MegOhm Meter currently used to measure isolation between connector pins.

Project Overview

- The number of permutations for the new tests results in a significant increase in the time and effort to perform these tests and also increases the opportunity for human error.
  - Phase A (7 pins) to (Phase B (7) and to Phase C (7)) is 7 X 14 = 98 tests
  - Phase B (7) to Phase C (7) is 7 X 7 = 49 tests
  - All Phases (21 pins) to ground = 21 tests
  - Total tests per receptacle = 168 X 12 receptacles per ship = 2016 tests

Fig. 2: 450 V Shore Power Connector

The Project

- Investigate the suitability of COTS equipment first and determine if such equipment can be adapted to this application.
- Should it prove suitable, develop any required modifications, including a connector to mate the equipment to the ship connectors, and program the equipment for the appropriate tests.
- If there is a fundamental issue with the equipment, the project will develop a design concept for switching the Megger measurement device between all the test permutations and offloading or recording the test data.
- If sufficient funds remain at this point, a prototype proof of concept device will be constructed.
- The goal is to develop a portable tester that can be plugged into the shore power connector and run the required tests at a single command or button push.

Project Team

- **The Penn State Electro-Optics Center** – project administration, requirements and test plans, evaluations.

PennState Applied Research Laboratory

- **D'Angelo Technologies, LLC** – programming and testing COTS equipment, recommending modifications.

D'ANGELO TECHNOLOGIES, LLC

- **Huntington Ingalls Pascagoula Shipbuilding** – Shipyard representative – arranging final demo

- **Gulf Coast SUPSHIPs** – government stakeholder – first identified the issue.

- **Project Technical Representative** – Walt Skalniak, Panduit Corporation.

- **NAVSEA 05Z IPT Members** – Chris Nemarich and Peter Andrich

Project Approach

- **Define firm requirements and test conditions for performing the required tests.**
- **A candidate COTS device has been identified that is potentially suitable.**
  - **It is the CableEye HVX High Voltage Cable Tester from CAMI Research (Acton, MA).**
  - **Nominally it tests a cable from end to end, but appears to be configurable to make the required measurements.**
  - **Portable table top device with interface to a laptop computer. Generates and records a full report in less than a minute.**
  - **In-house at D'Angelo Technologies, LLC and available for tests.**
- **Perform laboratory tests on the COTS device, including developing of programming to perform the required test. Simulate low and high impedance connections via resistors.**

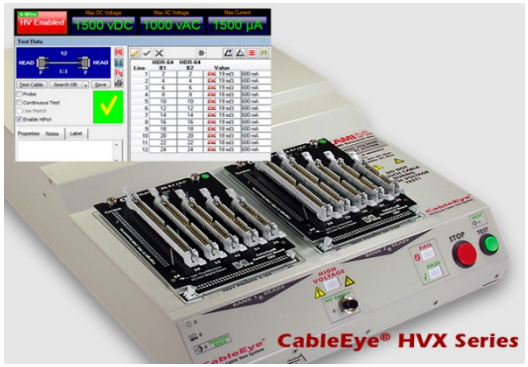


Fig. 3 CableEye HVX High Voltage Cable Tester

CAMI Research, Acton, MA.

Project Approach (cont.)

- Mate an appropriate cable and connector to the tester for testing with a shipboard connector.
  - Perform initial testing with a surrogate connector and mating connector with the appropriate number of contacts.
  - Purchase the same connector pair used for shore power connections and modify them for use with the cable tester.
- Discuss with the shipyard to determine if a realistic test can be made aboard ship or in another test facility to verify the prototype tester performance in actual tests and whether a detectable failure can be simulated.
- Perform this test and collect data if schedule and availability can be worked out.
- Identify the path forward for implementation.

Project Task Status

Task 1- Review Project Requirements along with Penn State and Gulf Coast SUPSHIPS to develop a requirements document
>> Complete. Kickoff meeting held Nov. 12, 2019. Test documents reviewed.

Task 2 - Assess CableEye tester applicability to requirements
>> Complete. Testing verified that tester could be programmed to make tests from one connector rather than end to end. Used surrogate connectors and simulated failures.

Task 3 - Program CableEye tester for laboratory tests and test against requirements
>> Complete. Actual shipboard connector purchased and modified. Macros programmed in tester to perform the test automatically.

Task 4- Host a simulation demonstration D'Angelo Technologies, LLC facility demonstrating the lab tests for Penn State, IPT members and invited participants.
>> Complete. Testing demonstrated for IPT for both good and simulated bad connectors.

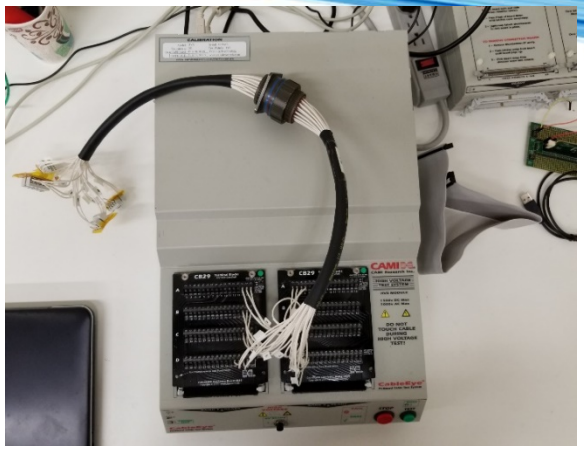
Task 5 - Support a field demonstration at a shipyard of equipment with actual connector.
>> Ongoing. D'Angelo Technologies preparing tester packaging for shipboard demo. NOTE: On hold due to COVID-19 travel restrictions. Reschedule TBD.

Task 6- Contribute to Quarterly and Final Reports as necessary.

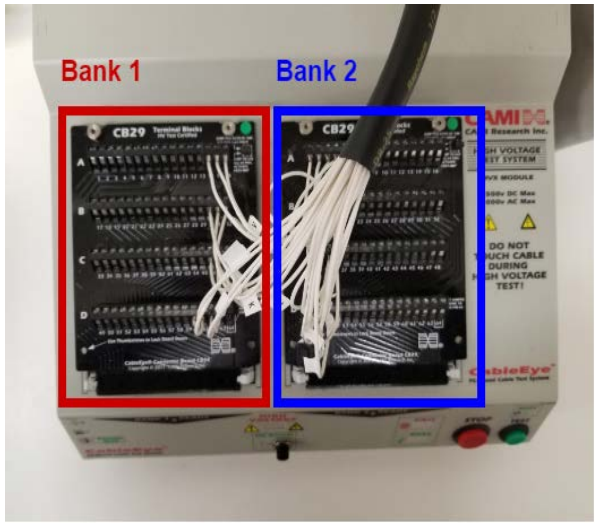
Technical Progress - 1

Programming worked out using surrogate connector

- Receptacle represents ship side, plug represents shore side
- Pins on receptacle side connected by phase (all 7 phase A together, all 7 phase B together, etc.)
- Pins on plug side connected to tester, but half for each phase to bank 1 and remaining to bank 2
- This allows tester to complete circuit through the pins connected on the back of the receptacle.



Surrogate cable connected to tester

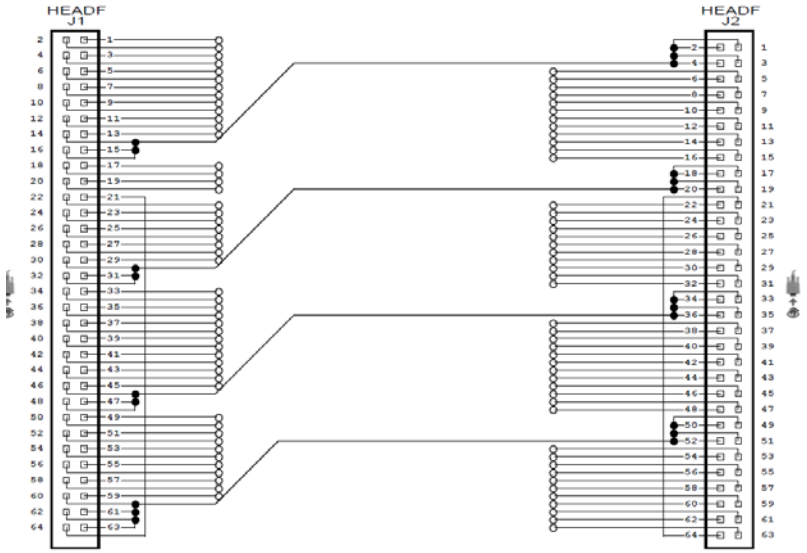


Wire connections to tester

Technical Progress – 2 – good cable

- Tester generates a schematic of what it sees connected or uses a stored schematic.

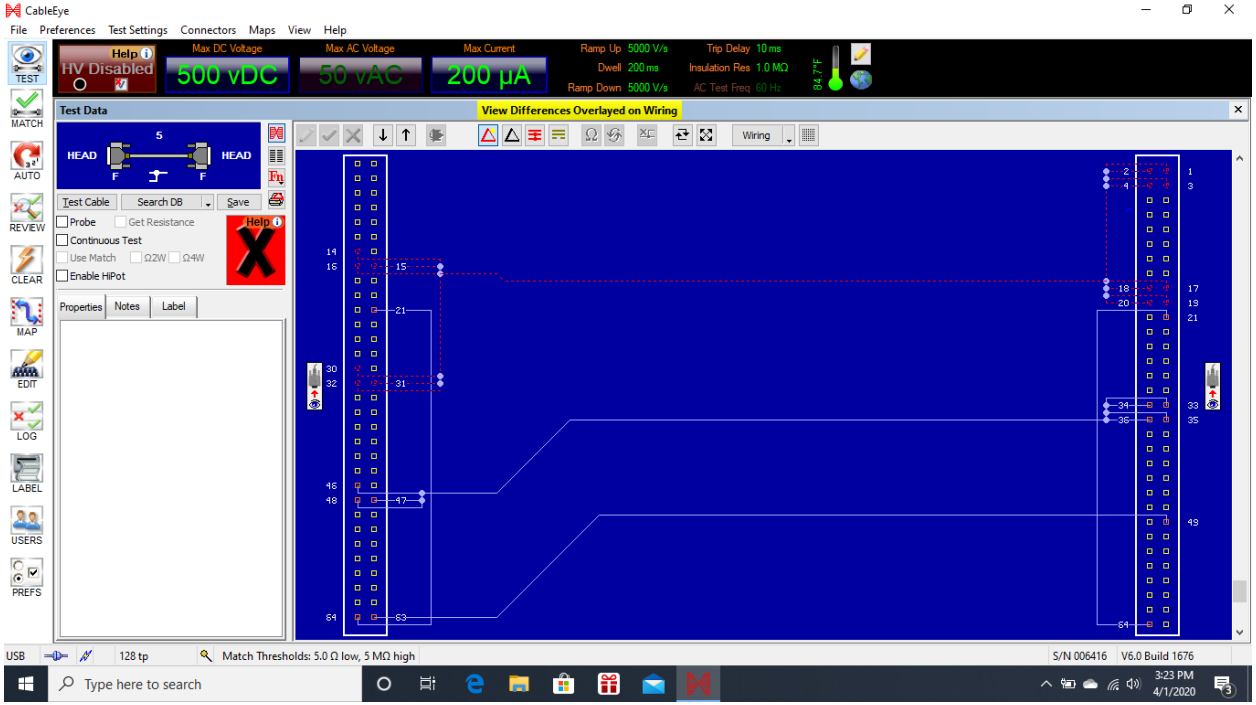
Good Cable Schematic



- Tester runs low voltage test comparing cable under test with stored schematic.
- If it passes, runs high voltage test. Parameters set to 500VDC and 1 MΩ pass/fail to meet test card requirements.
- Test takes 51 seconds to complete and checks every terminal pin against every other.

Technical Progress – 3 failed cable

- A low impedance fault was simulated by connecting a resistor between two of the tester terminals representing different phases.
- During low voltage test, tester identifies difference between test cable and stored connection and flags it with Failure Mark (X on Red) and schematic highlighting problem. HV test not run.
- Other fault simulated by resistor in series with one connection – simulating one corroded pin.



Failed Cable showing unintended connection between Phase A and Phase B (red lines)

Technical Progress – 4 Ship Connectors

- The actual shore power plug was modified to bring a wire out from each pin so that the pins could be individually connected to the tester
- The receptacle pins were wired together by phase the same as the surrogate receptacle.
- A ground connection was added (clipped to receptacle)

Tester connected to shore plug (L) with ship receptacle (C) shown

Technical Progress – 5 Lab Demo

- The setup shown on the previous slide was demonstrated at D'Angelo Technologies' facility on Feb. 20, 2020 for some members of the IPT. A summary report was sent to those who could not attend in person.
- Feedback from the IPT included:
  - The cable tester configured in this manner can perform the required shipboard tests
  - It is permissible to use the ground clips to the receptacle bolts to provide a ground connection for the test.
  - This was a good proof of concept demonstration using a benchtop COTS tool adapted for the purpose.
  - However, a practical tester needs to be simplified. Ideally it would all be built into the plug, with an on/off switch and a pass/fail indicator. Data could be saved or extracted as necessary, but would not be part of the normal day to day testing.
  - The question was raised about calibration requirements and who might perform the calibrations.

Next Steps

- Package Tester and shipboard connector to facilitate shipboard demonstration
- Arrange demonstration on board ship (Were planning May 2020, but now on hold due to COVID-19 travel and work restrictions. Applying for 3 month no cost project extension)
- Develop concepts and path forward for converting to a practical everyday test
- Write final report with results and recommendations

Project Benefits

- **The former test procedure required 6 tests (phase to phase and phase to ground), manually performed on 12 connector or 72 tests. The new requirement changes this to 2016 tests, or a x28 increase in labor effort and time. An automated tester can check each connector in about 2 minutes or roughly one half hour for all the tests, a significant savings in labor.**
- **Once the tester is completed, acquisition costs are fixed.**
- **Another strong benefit is the reduction in potential for human error.**
  - **Each of these tests is repetitive and the connector pins are identical in appearance.**
  - **The sheer number of identical tests increases the likelihood of a mistake being made.**
  - **Manual recording of data is also prone to error.**
  - **An automated tester that performs all the combinations of tests and records the data eliminates these sources of error.**
- **The recording of impedance measurements of the same connector over time can yield information on whether corrosion is starting to affect the integrity of the pins. This allows replacement of pins before they fail or show external signs of degradation.**
- **Exact cost estimates for the tester acquisition will be determined by how the design develops during the course of the project. The benefits are extendible to all ships using this type of connector, or to other connector types by substituting the mating connector on the tester.**

Deliverables

Deliverable	Team Member(s)	Due Date
Quarterly Reports	PSU, D'Angelo	10/31/19, 1/31/20, 4/30/20
Laboratory Demonstration	D'Angelo, PSU, Other IPT as available	2/20/20
Practical Demonstration	HII Pascagoula, PSU, D'Angelo, SUPSHIPSGC	4/22/20 (NOW TBD)
Final Report with Recommendations	PSU, D'Angelo, HII Pascagoula, SUPSHIPSGC	7/31/20 (NOW TBD)