

Advanced Technology 2013038 Portable End-to-End Test System (PETS) Final Project Report

Developed by
SCE Transmission & Distribution, Advanced Technology
Organization



Address
Southern California Edison – Advanced Technology
14799 Chestnut St.
Westminster, Ca 92683

Disclaimer

Acknowledgments

Prepared for: Southern California Edison, Advanced Technology, Public Utilities Commission of the State of California

Prepared by: Aleida Gonzalez

Principle Investigators (s): Christopher Clarke, Aleida Gonzalez

Change Log

Version	Date	Description of Change	Project Report No.
0.01	20160121	First revision	PS-13-038
0.02	20160218	Final version	PS-13-038

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Preface

1 Executive Summary

The intention of this demonstration project is to develop a Portable-End-to-End Test System (PETS) tool to conduct end-to-end testing of relay protection equipment using a portable Real Time Digital Simulator (RTDS) at each substation connected to the line under test. The test is designed to provide realistic fault simulations in order to prove that the entire relay protection schemes are properly configured including physical wirings. Aside from being able to conduct existing End-to-End test procedures which focus on the relay, the tool would be able to test the system as well. More specifically the tool would be able to test all communications pertaining to the line being tested and run a large number of disturbances using an automated script to identify a pass or fail based on predetermined SCE test criteria. Test reporting procedures would be similar to what is performed in the RTDS lab today to ensure that all performed tests are properly evaluated. This project does not support any existing regulatory proceedings. However, relay testing falls under NERC/WECC bulk power reliability criteria. Therefore, this project, as a proof of concept has the potential to increase the reliability of our protective schemes via rigorous testing and thus demonstrate SCE's proactive approach towards reliability.

The first step was to overcome the difficulty of being able to sync the simulation of the system under test using the portable RTDS units located at different substations. Close collaboration with the software developer resulted in an addition of a case start timer to the simulation software, which allowed the start time be synchronized. After a few delays in ordering the necessary equipment, test cases, scripts and draft test plans were created to test a two and three point line end-to-end relay test utilizing the prototype PETS tool. Preparations were made to conduct a preliminary test under a control environment in order to test the prototype prior to field testing.

In the process of developing the methodology to perform the test in the field, and through feedback from the end-users it was discovered that there were a limited number of test scenarios where the tool would be a great improvement over existing test procedures. As a result the project team concluded that there was no substantial value in further pursuing the development of the PETS tool. Although the tool would be an improved method of testing system performance when conducting end-to-end relay tests, the implementation of a companywide Portable End-to-End Test system (utilizing a Real Time Digital Simulator system) would not be cost effective when compared to traditional test methods. The major aspects that would drive the cost of implementing the PETS projects are:

- Development of specialized training would be required for field crews to be able to use the tool
- Availability of the tool; it would be extremely costly to purchase several PETS test sets to accommodate the different regions within SCE's territory when compared to purchasing existing tool in use
- Dedicated engineering staff to support issues related to maintenance and training

After careful deliberation of the benefits associated with proceeding with the PETS project, the team concluded that the tool did not provide value to the rate payers, except for demonstration purposes. Notwithstanding the innovation of the tool, it is not currently a viable option. Furthermore, the early close-out of this project does not impact how protection schemes are tested today as it was intended to be a proof of concept demonstration project.

2 Project Summary

The intention of this demonstration project is to develop a Portable-End-to-End Test System (PETS) tool to conduct end-to-end testing of relay protection equipment using a portable Real Time Digital Simulator (RTDS) at each substation connecting the line under test. The RTDS is a computer that is capable of simulating electric power system transients in real time. It has hardware in the loop (HIL) capability and can simulate system conditions and implement the closed-loop response of the device under test. The PETS tool test is designed to provide realistic fault simulations in order to prove that the entire relay protection schemes are properly configured including physical wirings.

2.1 Project Objective

PETS will provide more thorough testing in fewer hours than required by traditional tests during commissioning and routing of transmission lines. Test technicians would be provided with more accurate and extensive test results which means higher assurance that critical transmission and distribution lines and components are operationally adequate and exceed NERC/WECC bulk power reliability criteria.

2.2 Problem Statement

The existing end-to-end protective relaying scheme provides for a limited testing of relay schemes. The PETS tool would provide an opportunity for more comprehensive testing of protective relay schemes at high voltage transmission lines. The PETS tool would:

- Be able to test system performance (currently there does not seem to be a method to test the entire protection scheme at the same time, for example provide the same currents and voltages to all the relays at the same time).
- Provide greater flexibility to test crews when performing 3 terminal end to end relay tests. Existing test set-up is limiting given that test personnel only have access to very few pre-determined fault scenarios. Typically the scenarios are created using past DFR recorded events, or created using comtrade files from previous tests. The PETS tool would provide flexibility in creating different fault scenarios where fault type, inception angle, location and resistance could easily be changed.
- Have the ability to test relays in adjacent positions at the same time by injecting the same faults. The adjacent relays would then experience a reverse fault and their behavior could be observed.

2.3 Scope

This demonstration project will explore the feasibility of developing and implementing an end-to-end relaying scheme test tool using portable RTDS, amplifiers and satellite clocks. The tool set would address 1) relay protection equipment, 2) communications, and 3) provide a pass/fail grade based on the results of automated testing using numerous simulated disturbances. When compared to existing tools, which provide a limited number of scenarios (disturbances) and focus on testing protection elements, the PETS project will additionally provide testing of system protection. It will also develop a process and methodology to perform such testing in the field. Tests will be documented using a reporting procedure used in the RTDS lab today, ensuring all test data is properly evaluated.

Initially the scope aimed to achieve three main tasks:

- Develop and validate RTDS power system model for end-to-end testing.
- Demonstrate in-lab test of 2 and 3 terminal lines using RTDS hardware-in-the-loop. Test plan document developed in-lab to be used during end-to-end field testing
- Demonstrate field test of a 3 terminal line using the RTDS in the field. Final report with results of end-to-end field testing and test procedure based on NERC requirements.

During the process of developing the methodology to demonstrate the in-lab test and development of documentation to perform end-to-end field testing, and through feedback from the end-users it was discovered that there is a limited number of test scenarios where the tool would be a great improvement over how the tests are conducted today. Although the PETS system would be an improved method of testing system performance when conducting end-to-end relay tests, the implementation of a companywide Portable End-to-End Test system (utilizing a Real Time Digital Simulator system) would not be cost effective when compared to traditional methods of conducting these tests. Also while in the process of preparing for the first demonstration, it became apparent that using the PETS tools would require specialized training that would not be readily available to field crews.

After reviewing the feasibility of company wide deployment of the PETS tools it was deemed prudent to discontinue the project in its early stages. The completed tasks include development of test cases, scripts and draft test plans to test a two and three point line end-to-end relay test.

Other factors that affected the development of this project were delays in ordering and delivery of equipment as well as group-reorganization.

2.4 Schedule

A high level schedule overview is presented in the following table:

Task Name	Duration
Authority to proceed	0 days
Spec & Procure Portable RTDS	4 Months
Create RTDS end-to end test tool	9 Months
Create test cases and Scripts	3 Months
Create and test reporting tool	3 Months
Test tool in field	2 Months
Train SCE stakeholders	2 Months
Create final report	3 Months
End project	0 days

Table 1 Project Schedule

2.5 Milestones and Deliverables

Table 2 shows a list of milestones and deliverables. Due to early close-out of project, a status of “cancelled” is shown in status column.

Milestone/Deliverable	Status
Specs & Procure Portable RTDS	Completed
Develop PETS tool	Completed
Create RTDS end-to-end test tool (Dec. 2014)	Cancelled
Create test cases & scripts (Dec. 2014)	Completed
Create and test reporting tool	Cancelled
Test tool in the field	Cancelled
Training SCE Stakeholders	Cancelled
Create final report	Completed
Final Report Out to Stakeholders	Completed

Table 2 Milestones and Deliverables

3 Test Set-Up/Procedure

PETS will employ portable Real-Time Digital Simulators (RTDS's) in substations at each end of the transmission line being tested (see figure 1).

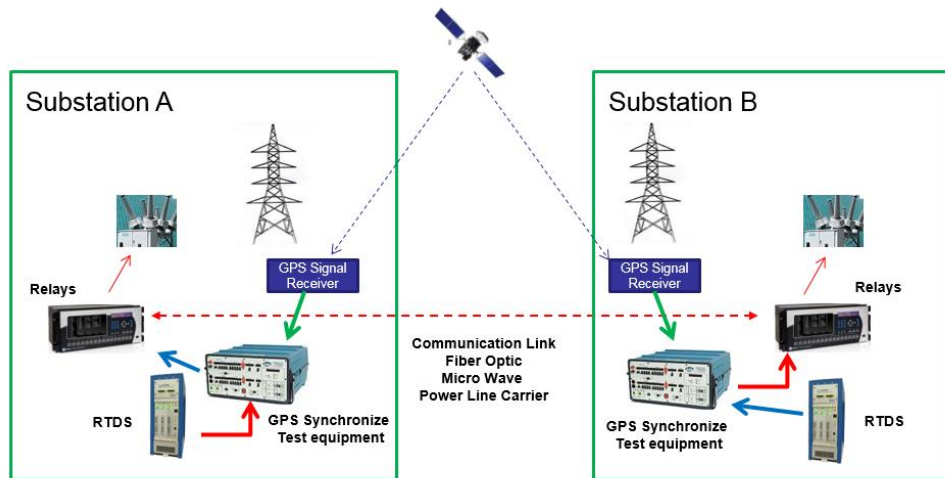


Figure 1 Test set-up

3.1 Software/Hardware

Different software interfaces were utilized in the development this project. RTDS modeling and validation was performed using RSCAD version 4.005. Load flow data was viewed and extracted using PSLF 18, and short circuit data was viewed and extracted using CAPE 2012. All scripting was done in Notepad++ and Microsoft Excel. ProtTest software was used to interact between relays and Doble test sets and GE Enervista was used to communicate with protective relays.

The hardware components of the PETS tool consist of Portable RTDS units, Doble test sets (voltage and current amplifiers), GPS clock and antenna for synchronization.

3.2 Test Methodology

There are two main stages to the development of the PETS tool. The first stage comprised of creating test cases, scripts and draft test plans in order to complete dry run in a control lab environment. In the second stage the tool would involve prototype lab testing and field tests. A multi-terminal (3-point) test would be conducted with a field crew at each location to test the full capabilities of the tool. 90 percent of the first stage was completed, the second stage was not achieved.

3.3 Test Case development

The initial test case development took place in the Advanced Technologies Power System Lab. A less complex 2 terminal end-to-end case was created in RTDS to test the start timer in order to perform synchronization tests.

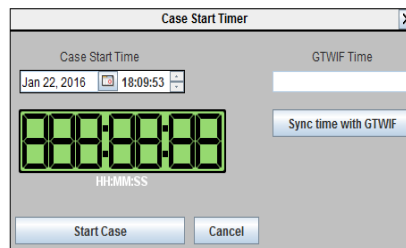


Figure 2 Start Timer

The RTDS simulates a model of the system under test and surrounding nearby area in real time. Every substation modeled contains a bus label and infinite source model. The label defines the bus name, voltage base, and type. The label information used show in table 3. After the model is built it can be manipulated through RSCAD Runtime. RSCAD Runtime provides two critical functions, 1) it allows the user to interact with and manipulate the simulation and 2) it enables the simulation results to be monitored and recorded. **Error! Reference source not found.**3 below shows the controls for the fault conditions. The slider, pushbutton, dial, and switch components are all model inputs that assign the value they are given in the Runtime to the associated variable in the draft model. Figure 4 shows a one line diagram of the two terminal test case with internal and external fault locations.

Bus Name	Short Name	Source P	Source Q	Load P	Load Q
Pardee	PAR	-	-	466.8	(117.5)
Sylmar	SY	1,134.0	(479.0)	-	-
Gould	GO	-	-	79.4	(74.0)
Eagle Rock	ER	-	-	132.9	5.0
Santa Clara	SC	-	-	223.7	(2.4)
Vincent	VIN	549.9	76.1	-	-
Goodrich	GR	(140.0)	(29.0)	-	-
Mesa	ME	-	-	412.0	15.7
Center	CE	-	-	110.6	23.6
Walnut	WL	419.1	1.6	-	-
Litehipe	LI	54.2	(3.2)	-	-
Redondo	RE	300.0	-	526.0	-
Rio Hondo	RH	-	-	464.4	(137.0)
Laguna Bell	LB	-	-	-	-
Del Amo	DELA	97.2	(19.8)	-	-

Table 3 Source Model Data

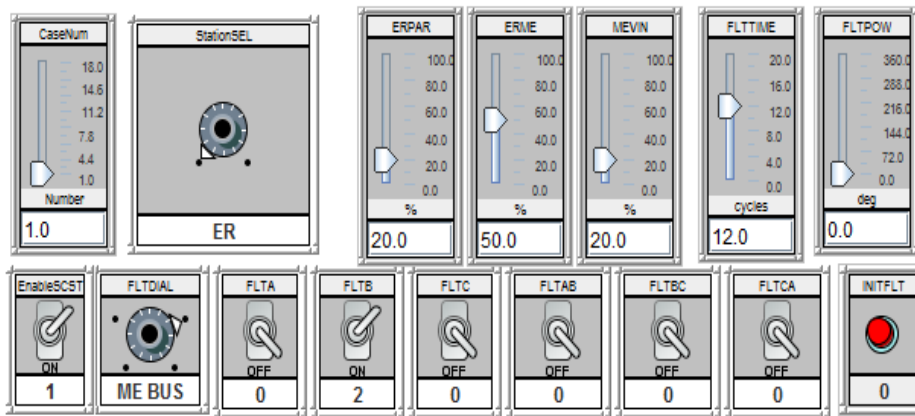


Figure 3 Runtime Controls

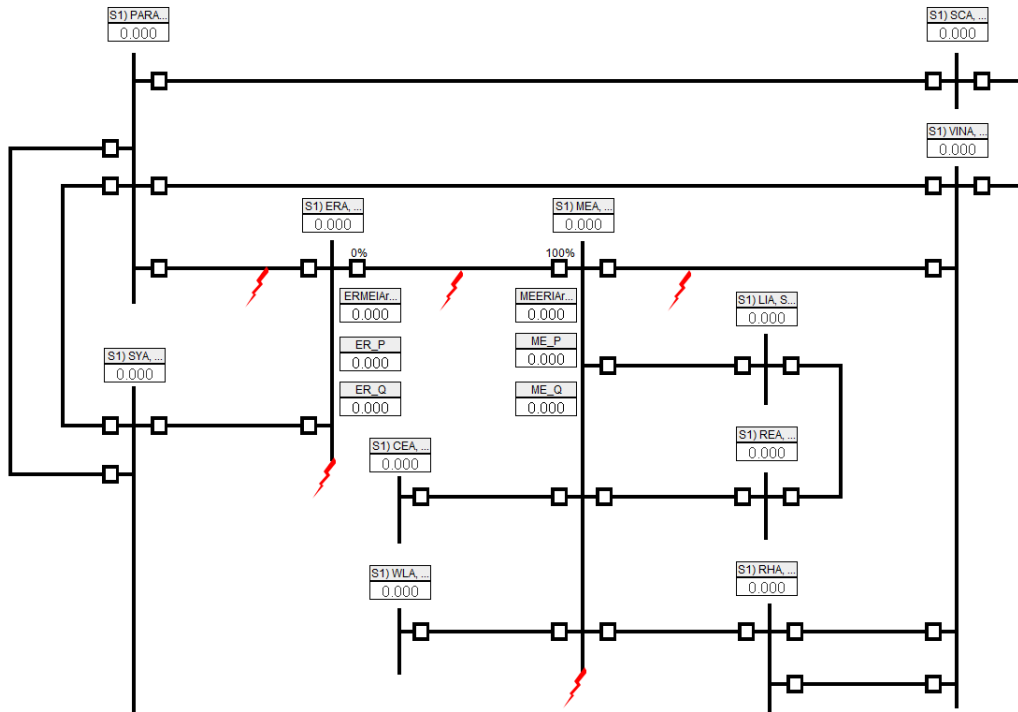


Figure 4 Two Terminal Oneline Diagram

Scripts were utilized in order to control the operation of the simulation and to collect and analyze the results. Figure 5 shows a snapshot of one of the scripts used to control and set-up the fault conditions and table 4 shows case scenarios that are used as inputs to the script.

```

4 MasterPlotLockState = 1;
5
6
7 dialoginput ( "Enter a scenario between 1 and 18: ",number);
8 sscanf (number, "%d" , num);
9
10 SetSlider "Subsystem #1 : CTLs : Inputs : CaseNum" = num;
11
12 if(num == 1)
13 {
14 //Red Bluff Bus - BG
15 SetDial "Subsystem #1 : CTLs : Inputs : FLTDIAL" = 5;
16 SetSlider "Subsystem #1 : CTLs : Inputs : FLTTIME" = 12;
17 SetSlider "Subsystem #1 : CTLs : Inputs : FLTPOW" = 0.0;
18 setFltType(0,1,0,0,0,0);
19 setDraftVar(20,50,50,20);
20 }
21 if(num == 2)
22 {
23 //Red Bluff Bus - AB
24 SetDial "Subsystem #1 : CTLs : Inputs : FLTDIAL" = 5;
25 SetSlider "Subsystem #1 : CTLs : Inputs : FLTTIME" = 12;
26 SetSlider "Subsystem #1 : CTLs : Inputs : FLTPOW" = 45.0;
27 setFltType(0,0,0,1,0,0);
28 setDraftVar(20,50,50,20);
29 }
30 if(num == 3)
31 {
32 //20% Beyond //Red Bluff Bus - CG
33 SetDial "Subsystem #1 : CTLs : Inputs : FLTDIAL" = 6;
34 SetSlider "Subsystem #1 : CTLs : Inputs : FLTTIME" = 12;
35 SetSlider "Subsystem #1 : CTLs : Inputs : FLTPOW" = 90.0;
36 setFltType(0,0,1,0,0,0);
37 setDraftVar(20,50,50,20);
38 }
  
```

Figure 5 Example of Script

Test No.	Description	Location (FLTDIAL)	Fault Time (FLTTIME)	Fault POW (FLTPOW)	FLTA	FLTB	FLTC	FLTAB	FLTBC	FLTCA
1	Right Bus - BG	2	0.20	0	-	1	-	-	-	-
2	Right Bus - AB	2	0.20	45	-	-	-	1	-	-
3	20% Beyond Right Bus - CG	1	0.20	90	-	-	1	-	-	-
4	20% Beyond Right Bus - ABC	1	0.20	0	-	-	-	1	1	1
5	Left Bus - AG	4	0.20	45	1	-	-	-	-	-
6	Left Bus - CA	4	0.20	90	-	-	-	-	-	1
7	20% Beyond Left Bus - AG	5	0.20	0	1	-	-	-	-	-
8	20% Beyond Left Bus - BCG	5	0.20	45	-	1	1	-	-	-
9	80% From Left Bus - AB	3	0.20	45	-	-	-	1	-	-
10	80% From Left Bus - CG	3	0.20	0	-	-	1	-	-	-
11	80% From Left Bus - BCG	3	0.20	90	-	1	1	-	-	-
12	80% From Left Bus - ABCG	3	0.20	45	1	1	1	-	-	-
13	60% From Left Bus - BG	3	0.20	90	-	1	-	-	-	-
14	40% From Left Bus - CA	3	0.20	0	-	-	-	-	-	1
15	20% From Left Bus - BC	3	0.20	45	-	-	-	-	1	-
16	20% From Left Bus - AG	3	0.20	0	1	-	-	-	-	-
17	20% From Left Bus - ACG	3	0.20	45	1	-	1	-	-	-
18	20% From Left Bus - ABCG	3	0.20	90	1	1	1	-	-	-

Table 4 Script Input Parameters

After successfully running the 2 terminal end-to-end simulation, a 3 terminal end-to-end test case was created, a one line diagram is shown in figure 6. Ultimately the 3 terminal test did make it to the actual field test.

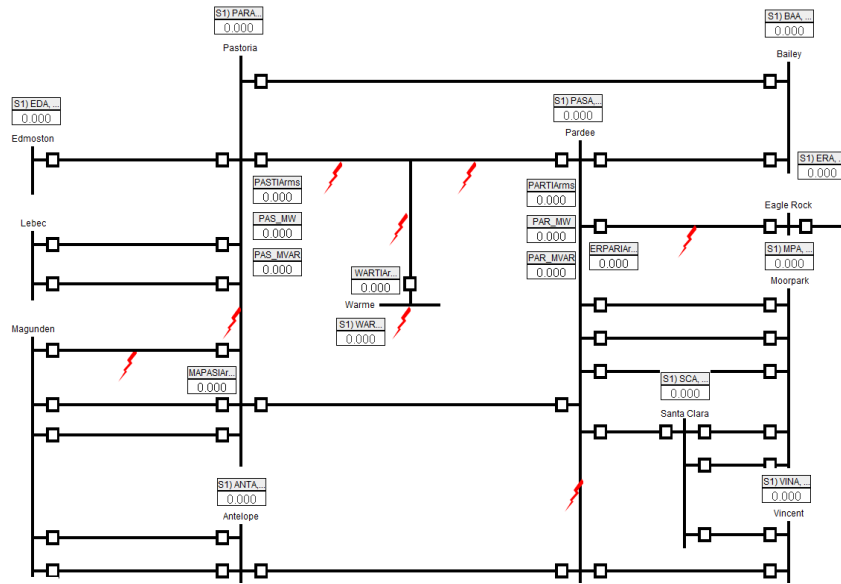


Figure 6 Three Terminal Online Diagram

3.3.1 Test Set-Up

The test set-up for the PETS prototype tool included the following equipment:

- 3 Portable RTDS units
- 3 Doble test sets (voltage and current amplifiers)
- 3 GPS Clocks
- 3 Antennas
- Protection relays

At each end of the line would be equipped with a portable RTDS unit, doble test set, GPS clock and antenna. Voltage and current signals from the portable RTDS are sent via a GTO interface card to the Doble test set which are subsequently transferred to the protection relays. The output scaling for the GTO cards is adjusted so that the primary voltage and current measurements read by the relay matches that of the RTDS RunTime. Selected relay signals are mapped to outputs on the relay and then physically connected to the Portable RTDS front panel interface. In RSCAD, the GTFPI component outputs all the digital signals as a 16-bit word. The individual signals are extracted using word-to-bit conversion components. GTO and GTFPI setup configuration are presented in figure 7 and 8 respectively.

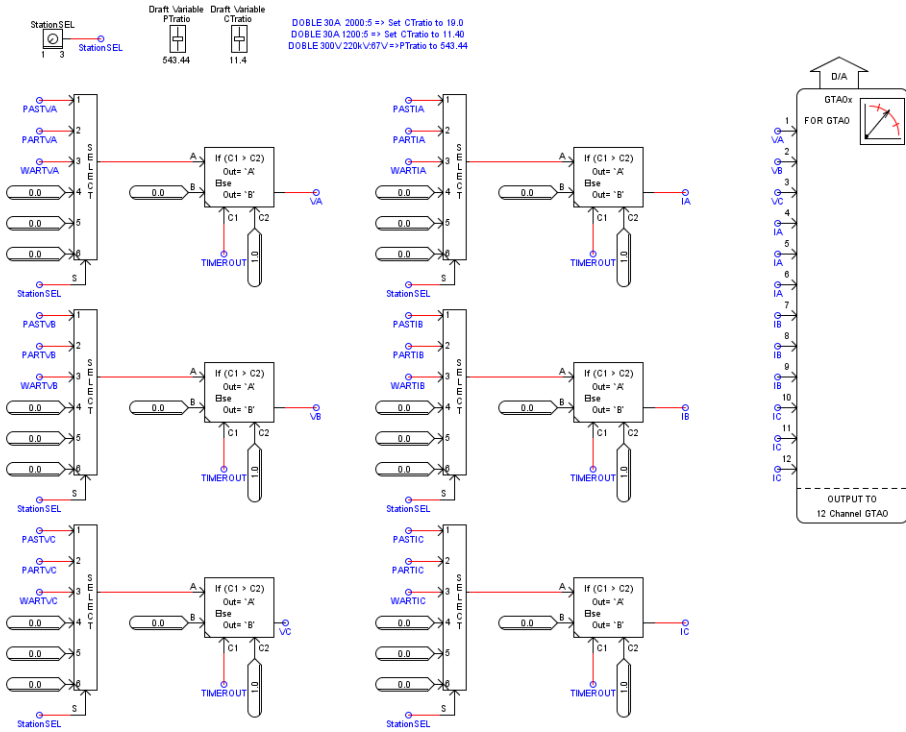


Figure 7 GTAO Setup Configuration

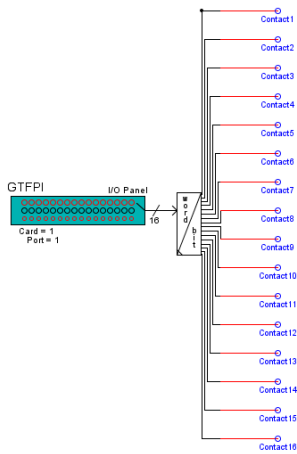


Figure 8 GTFPI Setup Configuration

4 Project Results

No results were recorded.

4.1 Technical Results, Findings, and Recommendations

Project may be revisited at a later time if it deemed that it would provide greater reliability at lower costs.

4.2 Technical Lessons Learned

The test setup yielded lessons learned that pointed the team to determining that this technology was not a viable option at this time.

For example, the test set up required significant power to drive 5 Doble test sets, as well as an outdoor area to set up a GPS antenna. Additionally the test setup needed to mirror field conditions (i.e., no external monitors, all test equipment needed to be transportable, etc.), so that we would be able to perform the test in a remote location without any unexpected events.

Furthermore, the setup required a mobile RTDS unit and Doble test set per terminal, meaning that 3 of each (RTDS unit and Doble test set) would be needed for lines that contained 3 terminals.

The team's analysis discovered however, that in our system very few 220 lines in fact have more than 2 terminals, and that the existing test systems were adequate options for testing 2 terminal lines.

4.3 Value Proposition

The objective of the PETS project was to meet EPIC's primary principle criteria of providing greater reliability to the customers. However, it was determined that the benefits associated with this demonstration project did not outweigh the costs and ultimately it would not provide added value.

4.4 Technology/Knowledge Transfer Plan

A technology transfer plan was not developed.

5 Metrics

The project was successful in proving that the tools exist to conduct advanced end-to-end relay testing, albeit not cost effective.

6 Appendix

List of Acronyms

AT	Advanced Technology (the organization)
EPIC	Electric Program Investment Charge
GPS	Global Positioning System
GTAO	Gigabit Transceiver Analogue Card
GTFPI	Gigabit Transceiver Front Panel Interface
PETS	Portable-End-to-End Test System
RTDS	Real Time Digital Simulator
SCE	Southern California Edison