Optimization of Turbine Performance Testing Through an On-Line Monitoring System

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Santee Cooper

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by

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Abstract

Optimization of turbine performance testing is becoming more of a necessity than an option for utilities today. Utility Managers need accurate performance tests results in less time and at lower costs to remain competitive in the emerging deregulated utility environment. Performance testing has traditionally been a time consuming, labor intensive exercise requiring advanced planning, scheduling and mobilizing cumbersome test equipment. At Santee Cooper, an on-line performance monitoring system has been adapted to reduce performance testing costs by eighty percent with similar improvements in response time.

Introduction

Santee Cooper maintains a dedicated performance test crew as part of the Performance Services Unit. The test crew operates from the corporate headquarters in Moncks Corner and serves all ten coal fired units with occasional testing assistance/expertise provided to other Departments. This unit conducts all of the performance tests for the Company. Until 1994, turbine cycle performance tests were conducted according to a prescribed schedule determined in the Fall of each year for tests to be conducted in the following year. With the completion of Santee Cooper's On-Line Performance Monitoring System (OLS), the opportunity to optimize current practices was made available. This paper describes the design and implementation of a program that has resulted in reduced per-test costs, response time and equipment requirements while maintaining accurate results.

Background

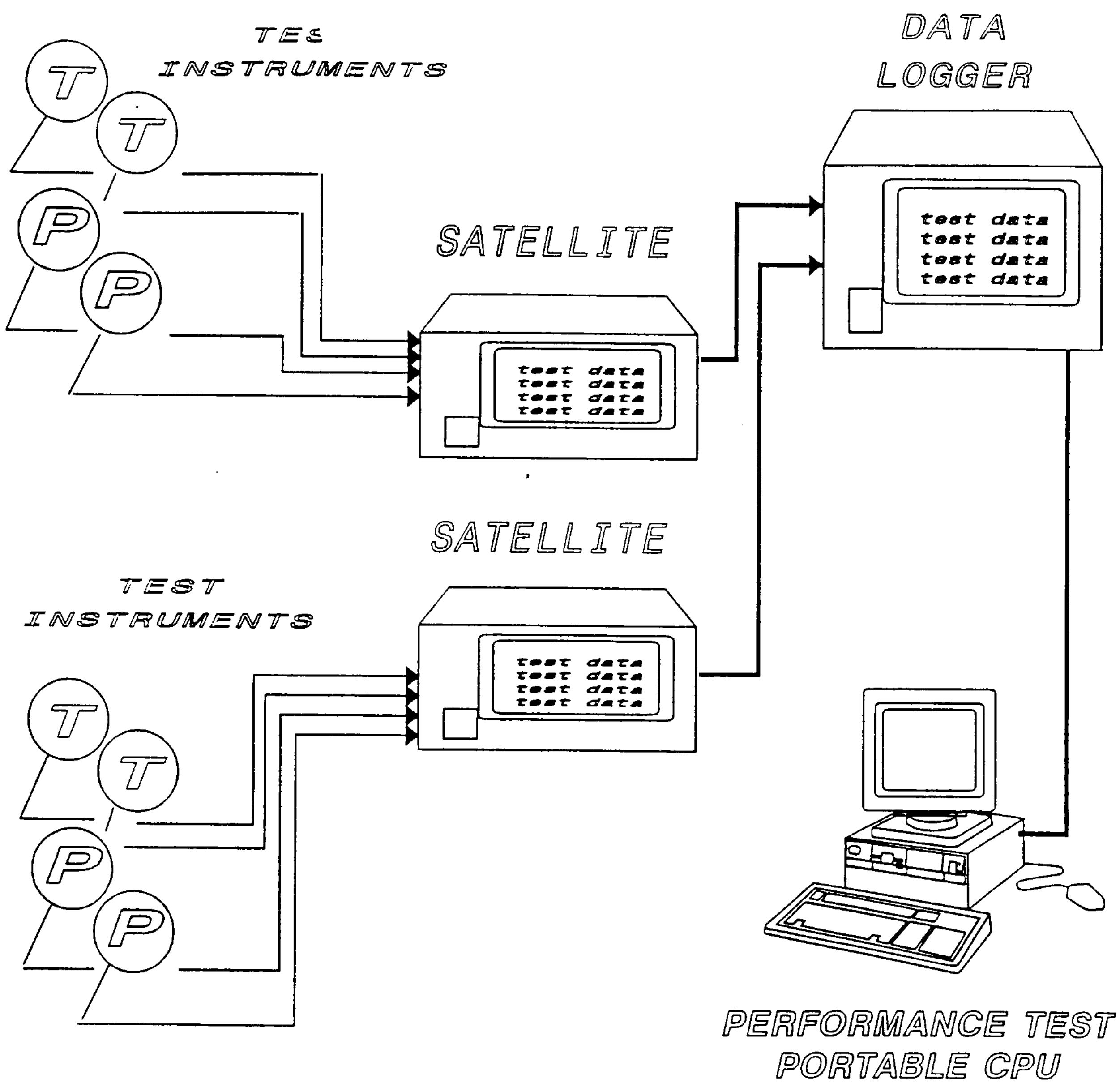
Santee Cooper has conducted annual performance tests on its coal fired units to determine rates of performance degradation of the turbine and major cycle components. Tests are also conducted prior to and immediately after maintenance outages to assess the benefits of the work performed.

The existing performance test data collection system configuration is shown in figure 1. A dedicated test crew consisting of one test engineer and two technicians perform all set-up, tear-down, data acquisition and performance testing. Set-up and tear-down for a typical test consumed, on average , three weeks labor. For each test, thousands of feet of instrument lead wire were pulled to connect over one hundred pressure transmitters and RTD's to as many as three data loggers. It was not uncommon for several lead wires to be damaged and replaced during tests. Instruments were installed at available locations throughout the system, often requiring technicians to work at heights or in cramped quarters and usually in high temperature environments. Installation of pressure transmitters required the use of a "pig tail" to connect the test point root valve to the pressure transmitter. This also required that water leg data for each pressure transmitter installation be measured and recorded in the test data acquisition software. Installation of differential pressure transmitters to measure feedwater flow required connecting in parallel to the station flow device transmitter. This procedure was difficult and required extreme care in order to avoid upsetting the unit.

Over the years, a number of efficiency improvements were incorporated in the test

PERFC ANCE TEST INSTRUMENTS

PRESSURE		TEMPERATURE	
1	Throttle BEF Y 1	1	Throttle N 1
2	Throttle BEF Y 2	2	Throttle N 2
3	First Stage 1	3	Throttle S 1
4	First Stage 2	4	Throttle S 2
5	Cold RH N	5	Cold RH N 1
6	Cold RH S	6	Cold RH N 2
7	Hot RH N	7	Cold RH S 1
8	Hot RH S	8	Cold RH S 2
9	Crossover 1	9	Hot RH N 1
10	Crossover 2	10	Hot RH N 2
11	BP NE	11	Hot RH S 1
12	BP NW	12	Hot RH S 2
13	BP SE	13	Crossover E
14	BP SW	14	Crossover W
15	Cond Pmp In	15	CW Out
16	Cond. Pmp Out	16	Cond. Pmp Out
17	Htr Drn Pmp Out	17	Htr Drn Pmp Out
18	Htr 1 In	18	Htr 1 In
19	Htr 1 Out	19	Htr 1 Out
20	Htr 2 In	20	Htr 1 Drn
21	Htr 2 Out	21	Htr 2 In
22	Htr 2 Bld	22	Htr 2 Out
23	Htr 2 Ext	23	Htr 2 Bld
24	Htr 3 In	24	Htr 2 Drn
25	Htr 3 Out	25	Htr 3 In
26	Htr 3 Bld	26	Htr 3 Out
27	Htr 3 Ext	27	Htr 3 Bld
28	Htr 4 In	28	Htr 3 Drn
29	Htr 4 Bld	29	Htr 4 In
30	Htr 4 Ext	30	Htr 4 Out
31	Htr 5 In	31	Htr 4 Bld
32	Htr 5 Out	32	Htr 5 In
33	Htr 5 Bld	33	Htr 5 Out
34	Htr 5 Ext	34	Htr 5 Bld
35	Htr 6 In	35	Htr 5 Drn
36	Htr 6 Out	36	Htr 6 In
37	Htr 6 Bld	37	Htr 6 Out
38	BFP In A	38	Htr 6 Bld
39	BFP In B	39	Htr 6 Drn
40	BFP dP 1	40	BFP Out A
41	BFP dP 1	41	BFP Out B
42	BFP Discharge		
43	BFP dP (sqrt)		
44	SH Spray W		
45	SH Spray dP E		
46	SH Spray dP W		
47	Barometric		



PERFORMANCE SERVICES

PERFORMANCE TEST COMMUNICATIONS | 5/24/93

FIGURE 1

procedures to minimize labor, materials and time required for performance tests while maintaining or enhancing quality of results. Further improvements would need to come through a review and possibly a re-design of the test methodology.

Approach

In 1994, construction of the OLS was completed at the Winyah, and Jefferies units and was in progress at Cross station. At that time, the system was mature enough that the opportunity to improve service to the stations and reduce costs by integrating performance testing into the monitoring and tending capabilities of the OLS could be explored. Time and motion studies were conducted by the unit to identify all aspects of the current performance test procedures (figure 2). With the idea of integrating the test function into the OLS in mind, engineers and technicians began optimizing the test procedure to eliminate as many steps and as much equipment as possible. Through iteration, an optimized system was designed (figure 3). Cost/benefit analysis was conducted on the optimized system design and forwarded to Management for review.

Design

Basic design constraints for an optimized system were identified as:

Minimize hardware, set-up and tear-down labor requirements per test. - Under the existing methodology, a considerable amount of hardware/equipment was required to conduct performance tests. Test schedules required maintaining sufficient equipment to instrument two turbines for performance tests at the same time. Thousands of feet of instrument leadwire, fittings, valves, tubing and extension cords were required for each test. The optimized design include hardwiring all remaining instrument points required for testing to the OLS data acquisition system.

Eliminate the need for dedicated data logging equipment for routine turbine tests and their associated maintenance costs. - Several data loggers and associated spare

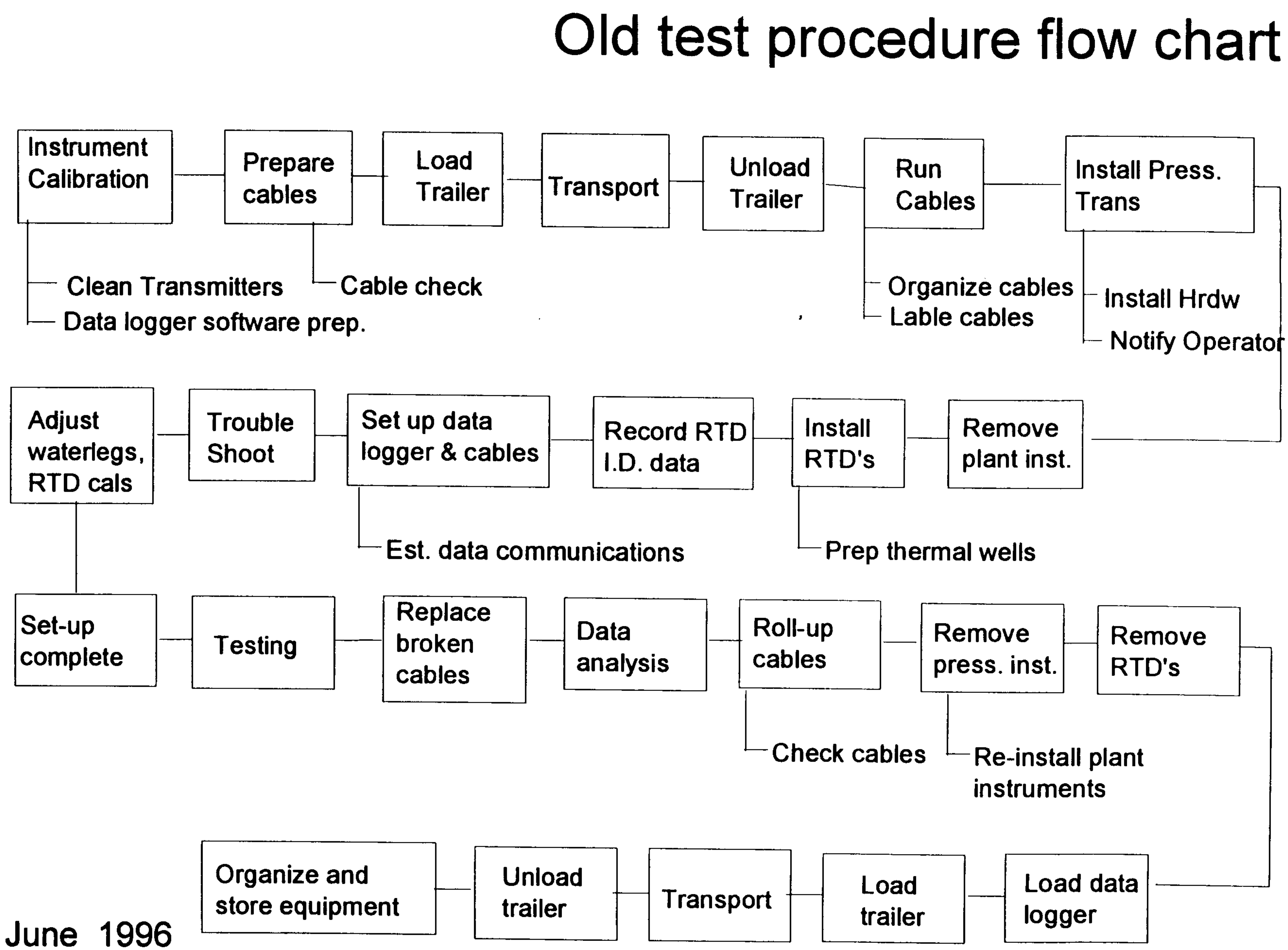
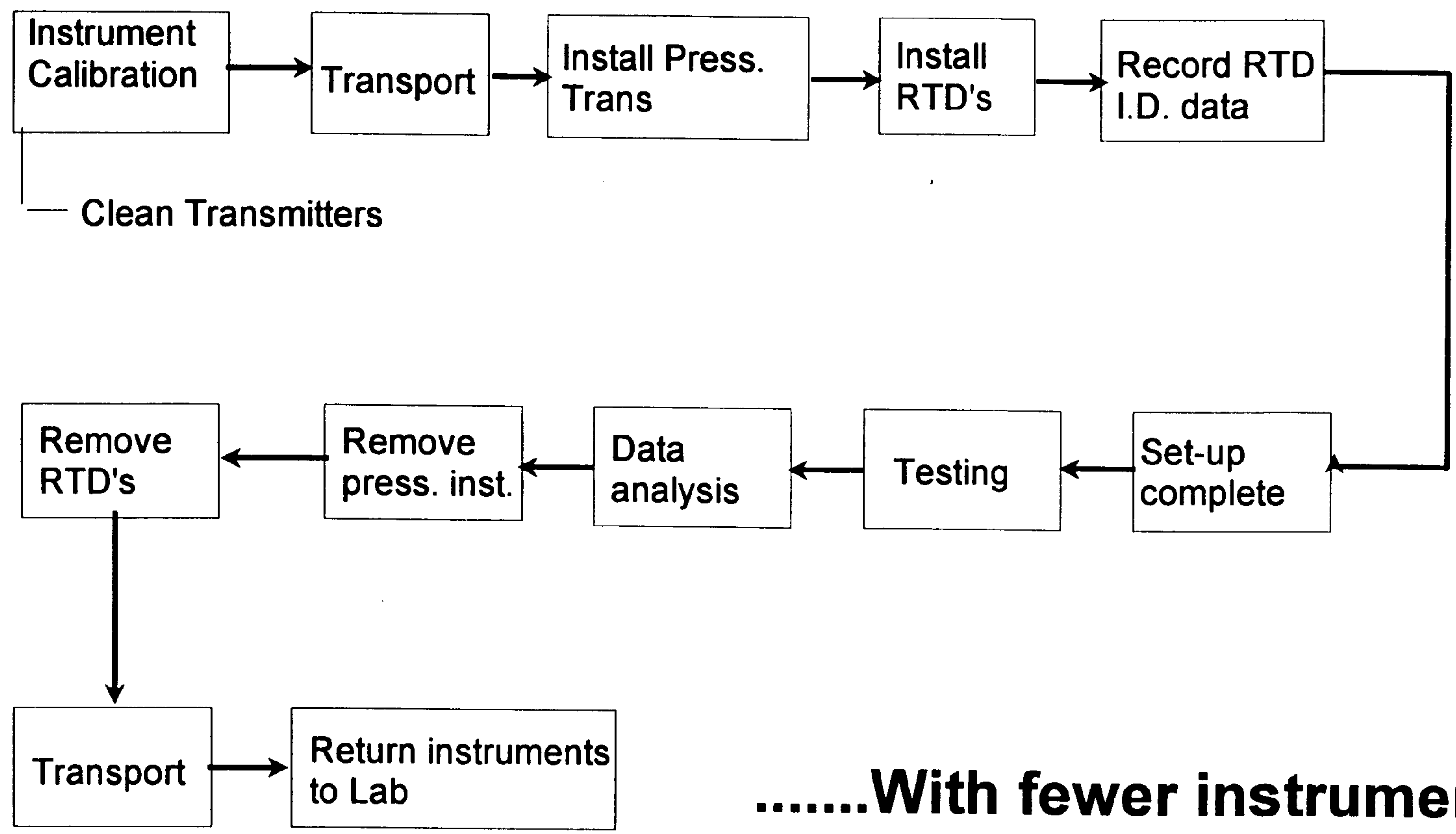

Old test procedure flow chart
Instrument Calibration
Prepare cables
Load Trailer
Transport
Unload Trailer
Run Cables
Install Press. Trans
Clean Transmitters
Data logger software prep.
Cable check
Organize cables
Lable cables
Install Hrdw
Notify Operator
Adjust waterlegs, RTD cals
Trouble Shoot
Set up data logger & cables
Record RTD I.D. data
Install RTD's
Remove plant inst.
Est. data communications
Prep thermal wells
Set-up complete
Testing
Replace broken cables
Data analysis
Roll-up cables
Remove press. inst.
Remove RTD's
Check cables
Re-install plant instruments
Organize and store equipment
Unload trailer
Transport
Load trailer
Load data logger
June 1996

FIGURE 2

Optimized test procedure flow chart



.......With fewer instruments

June 1996

FIGURE 3

parts were required to meet test schedule commitments. Although functional, much of the data logging equipment used for performance tests was at least eight years old and near the end of its design service life. Costs for replacement parts and repairs were increasing. The optimized system design effectively replaced the test data loggers with the data acquisition system of the OLS. This design feature served two purposes; first, it eliminated the need for replacing an aging inventory of data loggers and second, it provided permanent test data logging capability at each station. Finally, this equipment was made available for improving response time in cooling tower testing and to the Performance Services Calibration Lab for use in performing on-site instrument calibrations (air heater temperatures for example).

Improve access to performance test data / results - The optimized design would also be required to allow access to the test data and results in a more timely manner. Management would be able to review test results, test reports and supporting data using the OLS networks.

Improve availability of test crew resources - The optimized design targeted reductions in manpower of 80 percent. The test crew would then be available respond to additional work requests that would otherwise not be possible and to assist in other areas such as with Air Quality Compliance Testing. Using the OLS, the test crew could not only extend their availability to others but take advantage themselves of other available resources. The optimized design would allow test data to be transmitted back to the Moncks Corner offices for review by the remainder of the staff. Since Santee Cooper maintains a mainframe version of PEPSE, performance analysis of test data must be conducted from an available mainframe terminal at the station or at the Moncks Corner office. This usually required an additional performance engineer at the site to complete the analysis the same day. A feature of the optimized design was to reduce this manpower commitment.

Reduce transportation equipment required for turbine tests - Transporting the large amount of equipment needed for performance tests required a dedicated equipment trailer and heavy duty equipment van to tow it to the stations. In addition, a number of equipment carts were required to install all of the instrument lead cable, instruments, tubing and data loggers. Since the equipment van was at the end of its service life, and in need of replacement, a goal was set to eliminate or reduce the size of the scheduled replacement vehicle by drastically reducing equipment hauling requirements.

Minimize exposure to safety hazards during performance testing. - Under the existing test set-up procedures, instruments were installed at available locations throughout the system, often requiring technicians to work at heights or in cramped quarters and usually in high temperature environments. A primary goal of the design was to re-locate or modify the access point for as many test instruments as possible to minimize exposure to safety hazards. The design called for:

1. Permanently installed half-inch stainless tubing connecting pressure taps to a centralized pressure instrument station accessible at floor level.
2. Move thermal wells to more easily accessible locations if possible, or install platforms and ladders to improve access.
3. Reduce employee exposure to heat by minimizing set-up and trouble-shooting time.

Implementation

Hardware - Implementation of the design was completed on a unit by unit basis. Hardwiring of test points was completed by Performance Services technicians. This tubing was routed to centrally located pressure instrument stations throughout the unit. These stations were then hardwired to the OLS instrument cabinet located in the unit's relay room. Temperature measurement locations were hardwired directly to the OLS instrument cabinet. During the implementation a number of design enhancements were adopted to further streamline performance test methods. These included special RTD quick-connects installed to minimize effort of installation and removal. These connectors also help minimize trouble-shooting by preventing improper RTD lead-wire connections since they can only be installed one way.

Test Software - The test crew uses a 586 portable PC with an OS/2 operating system. This allows the test crew to record, download and process test data simultaneously on the same PC. Customized performance test data collection software was developed for each unit due to minor differences in the units. Individual test software is stored on the test PC and called up as needed. It is important to note that since the units are now hardwired for performance tests, most of the previously dynamic test set-up information such as instrument location/channel number, water legs, etc. are now static and are programmed into the test software for each unit. This eliminated days of effort for each test.

Data Processing/Networking - Santee Cooper's OLS is configured as a Wide Area Network (WAN) composed of a dedicated Local Area Network (LAN) at each station and at the Corporate Offices in Moncks Corner. Similar to PMAX, the OLS collects performance data, performs instrument verification and performance calculations, and posts results to the network continuously at five second intervals. Optimization of performance test data acquisition included taking advantage of this existing data acquisition and network capability. Using the OLS WAN it is also possible to acquire test data on any OLS equipped unit directly from the Corporate offices. This has proven useful in reducing travel time, sneakerware and response time in evaluating performance data. For example, on a recent turbine acceptance test, three functions were being performed with performance test data simultaneously. At the Station, 1) The test engineer was collecting data on the unit and reviewing test procedures/ contract requirements with the vendor and Station Manager. At the Corporate Office, 2) Performance Services engineers were receiving test data, executing PEPSE analysis and reviewing results, and 3) Generation Technical Services and Generation Maintenance engineers were reviewing test data in real-time at the Corporate Office.

Review

Construction was initiated in August 1993 with a budget of $140,000. A total of 285 instrument locations were hardwired for inclusion in the OLS. The project was completed in August 1995 under budget. The extent to which the redesigned test procedures reduced costs was demonstrated most recently during the Jefferies 3 turbine performance test in May 1996. Testing was conducted in three days. Test crew labor costs were reduced by over 80 percent from 180 man-hours to 30 man-hours. Calibration lab labor costs were reduced by over 40 percent from 70 man-hours to 40 man-hours. Lead time between requests for tests to actual data collection was reduced by over 80 percent from six days to one day. Equipment requirements were also significantly reduced. Four Data loggers and a dedicated test equipment trailer were re-assigned for other uses. A planned replacement for the test crew vehicle was dropped from the budget. Test instrument lead cables were eliminated.

A number of intangible benefits of utilizing the OLS for performance testing have been realized such as improved resource sharing between the test crew and OLS support crew, reduced effort and time in trouble shooting, and improved appearance of the test set-up. It is important to note that one of the most critical elements to the success of the project was the input from the test crew, laboratory and OLS support crew technicians.

Added Benefits

In addition to the original goals of the project, benefits have been realized as a result of the optimization project in other areas. Bi-weekly enthalpy drop tests are conducted on all seven OLS equipped steam units in the Santee Cooper system. These tests provide valuable information to Management on the condition of the turbine cycle on a much more frequent basis than annual performance tests. This capability is used to trend turbine efficiency and component performance between annual tests and in identifying the root causes of gradual and abrupt changes in performance. This information is also valuable to the test crew in preparing for performance tests. Problems with component performance such as feedwater heater level and control problems, leaking valves, changes in N2 packing leakage rates and turbine valve control problems are reviewed prior to scheduled testing. Excess travel time has been avoided by allowing the technicians to identify any failed instruments installed on a particular unit prior to traveling to the station. Formerly, technicians had to travel to the station, inspect the instrumentation, identify failed instruments, return to the lab for replacements, travel back to the station and then install the new instrument.

Planned Enhancements

To further streamline maintenance and trouble-shooting, Performance Services is currently developing an automated calibration data management system for use with the OLS. This system will link the Performance Services Calibration Lab instrument databases directly with the OLS wide area network. When completed, technicians will be able to access the Moncks Corner laboratory database, check calibration data and down-load instrument calibration information directly to the station OLS. The database automatically updates the OLS instrument inventory.

A Graphical User Interface (GUI) is in development specifically for the test crew to facilitate automated processing of test data for PEPSE analysis.

Conclusions

Competition in the utility industry is forcing providers to look for innovative ways to reduce operating costs. Timely access to performance data plays an important role in decisions by utility Management. Optimization of the collection, analysis and presentation of performance data to Management is essential to remaining competitive. Santee Cooper has optimized the business of performance testing through the successful integration of the testing function into on-line performance monitoring resulting in significantly reduced department operating costs while improving the quality and timeliness of service to Management.