

Advanced Test Report Management & Data Mining

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ABSTRACT

The major purpose of performing electrical maintenance testing is to identify faulty devices and to document devices that are operating properly for liability reasons. Based on these goals performing the tests is only the first step in accomplishing this task.

This paper will address several additional steps including report generation, defect tracking, trending for predictive failure analysis, and web access. The paper also discusses the PowerDB software application that aids in the previously mentioned tasks and facilitates the moving of test data to enterprise wide preventive maintenance packages such as Maximo.

INTRODUCTION

It is standard practice for companies to use relational databases for managing some aspect of their business, for example: contact management, project time analysis, and work order generation. Work order generation – certainly an important part of the process of preventive maintenance – is often triggered by an asset's maintenance time interval. The use of Computerized Maintenance Management Software (CMMS) systems, such as Digital Inspection's Cascade and MRO Software's Maximo, improve this process by moving toward test scheduling based on equipment health. If the detailed test results are also stored in a relational database, then the process of preventative maintenance can be further improved by data mining test results to statistically determine trends toward equipment failure.

TEST DOCUMENTATION AND DEFECT TRACKING

A relational database is an ideal tool for maintaining test documentation. Test results stored in a relational database can be associated with a particular asset, or piece of equipment, so that a history of testing details is maintained. When all of an organization's preventative maintenance test results are stored in a central location and available by query, then the results are readily available when they must be produced for liability reasons. This solves the problem of finding misplaced data files or hardcopies when they are needed.

If some basic asset information, such as serial number or other identification, is also maintained in a test documentation database then test results could be used to trigger a work order in a CMMS system. The test results used to trigger work orders could be as simple as the presence of a deficiency noted during testing that could then adjust the priority or period for preventative maintenance scheduling.

If particular data entry fields are denoted as deficiency fields, then a report summarizing deficiencies across a group of equipment could be generated.

As the amount of data grows for similarly configured equipment the database becomes useful for predicting equipment failures.

DATA MINING

Data mining for trends and shifts in preventive maintenance test data can give an accurate indicator of equipment health. Schweitzer Engineering Laboratories published a technical paper *Understanding, Predicting, and Enhancing the Power System through Equipment Monitoring and Analysis*.¹ This paper describes monitoring equipment over time, collecting data in a centralized database, and trending data to determine equipment health. IBM has implemented data collection and analysis in some of their products, and has appropriately named and trademarked the process as Predictive Failure Analysis®.² The process allows computer components to be changed at a scheduled downtime before failure occurs.³

Given an association between a piece of equipment and the historical test data, then trends and sudden shifts in data can be discovered. A *trend* can be defined as n consecutive steps in the same direction by a particular test point.

Given an association between a piece of equipment, the configuration, the test data and deficiencies noted, then the mean and n -sigma band can be determined for any particular test point.

One example of a trend chart could present information about a test point by plotting data vs. time for a particular piece of equipment, i.e., its preventative maintenance test data history. The manufacturer's limits and an n -sigma band (where n is small, e.g., 2-sigma) for all similarly configured equipment can also be displayed. It may be useful to also display all of the data points for similarly configured equipment. By visual analysis of the chart, it would be easy to see if the equipment is nearing the limit (or has exceeded the limit) of the acceptable n -sigma band and may be moving toward failure. An example of a trend chart is shown in Figure 1.

Programmatically analyzing this data is also possible in order to identify trends and data nearing (or exceeding) the acceptable n -sigma band. This information can then be used in a "failure prediction report", or to trigger a work orders in a CMMS system.

¹ Dolezilek, 2000

² <http://www.ibm.com/legal/copytrade.shtml>

³ <http://www.storage.ibm.com/ipl/oem/tech/pfa.htm>

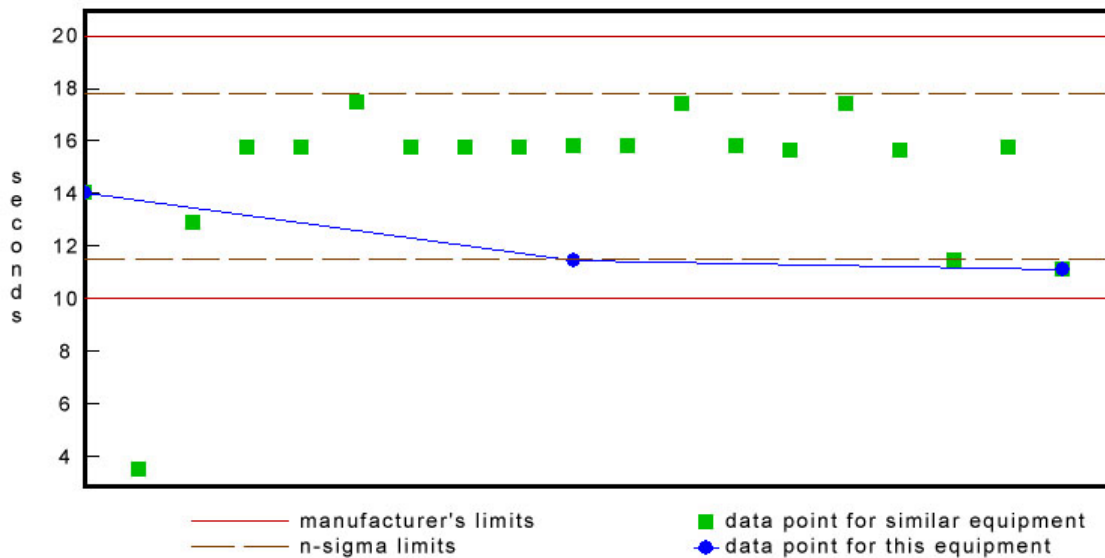


Figure 1: Trending Example

REPORT GENERATION

In addition to the data relationships described previously, assets stored in a relational database can be associated with particular work-orders and a location. This allows reporting in order to document tested equipment. For example, all of the test result sheets associated with a particular work-order could be gathered and printed in a single step. In addition, summary reports could be generated, for example denoting deficiencies across the test sheets.

Without test data in a relational database and software to automate the process, an employee may have to collect, sort, open, and print hundreds of word-processor or spreadsheet files. Moreover, generating a summary report would require inspecting each form for deficiencies noted, copying the text, and pasting into another word-processing document. Besides the tedium of manually constructing a summary of deficiencies, it is error prone and equipment problems may go unaddressed.

IMPLEMENTATION WITH POWERDB

PowerDB, a commercial software package by Optima Systems, Inc., addresses the problems presented in this paper. It has been used successfully by utilities, chemical and manufacturing plants, and electrical testing contractors.

TEST DOCUMENTATION

Test documentation in PowerDB is accomplished in three ways: manual data entry, importing data from other sources, and data acquisition from test instruments. Manual data entry is done on screens identical in layout to the printed test forms. Figure 2 shows the data entry screen for a two-winding transformer insulation test. Values can be typed into any of the data entry fields. Navigation through the form is done with the tab and arrow keys, taking the user to the next field typical for the testing procedure.

Megger. **INSULATION TESTS** **TWO-WINDING TRANSFORMERS** **POWER DB**

CUSTOMER: ABC Service Center PAGE: 1 of 7
 ADDRESS: _____ JOB #: Z1037
 USER: Bryan Middle School; 320 East Grand River Avenue; Dallas TX 77845
 MAXIMO Work Order # _____ MAXIMO ID# _____ TELEPHONE _____
 DATE: 4/20/2004 TEMPERATURE: _____ °F HUMIDITY: _____ % EQPT. LOCATION: _____
 SUBSTATION: MAIN BUILDING POSITION: TR #32

TRANSFORMER: _____ MFR: _____ SERIAL NO: _____ WEATHER: _____ TOP OIL TEMP: 23
 MFR YEAR: 1980 TYPE/CLASS: _____ KVA: 500 GALLONS OF OIL: _____ DATE LAST TEST: _____ LAST SHEET NO.: _____
 OIL: ASKAREL AIR GAS SILICONE FREE BREATHING: SEALED: GAS BLANKETED: CONSERVATOR:
 COPIES TO: _____ MFR: _____ TYPE / CLASS: _____ DWG. NO.: _____ CAT. NO.: _____ KV: _____ YEAR: _____
 HIGH SIDE: KV: 12 WYE: DELTA: GENERAL ELECTRIC: _____ CTF (85-330 KV) _____
 LOW SIDE: KV: _____ WYE: DELTA:
 NEUTRAL: _____

TEST NO	INSULATION TESTED	TEST MODE	TEST CONNECTIONS (WINDINGS)				TEST KV	CAPACITANCE C (PF)	% POWER FACTOR			EQUIV 10KV		INSULATION RATING
			ENG	OND	9AR	UST			MEASURED	20 C	CORR FACTOR	mA	WATTS	
1	C _{H0} + C _{HL}	OST OND	H	L						0.940				
2	C _{H0}	OST	H		L					0.940				
3	C _{HL}	UST	H		L	5.08	948.05	10.08	0.46	0.940	1.823	3.5960		
4	C _{HL}		TEST 1 MINUS TEST 2											
5	C _{L0} + C _{HL}	OST OND	L	H						0.940				
6	C _{L0}	OST	L		H					0.940				
7	C _{HL}	UST	L			H				0.940				
8	C _{HL}		TEST 5 MINUS TEST 6											
9	C _{H0} '		C _{H0} MINUS HIGH BUSH.											
10	C _{H0} '		C _{L0} MINUS HIGH BUSH.											

BUSHING TESTS

Figure 2: Data Entry & Automated Control of Megger DELTA-2000

Importing data can be done from files designed for PowerDB by an equipment manufacturer or analysis laboratory. For example, Weidmann-ACTI can provide a single file to be imported into PowerDB that will automatically populate hundreds of test forms with the analysis of your transformers done by their laboratories. PowerDB test forms can also be designed to interact with other testing applications, such as Megger's AVTS, which allow the population of test forms in PowerDB as tests are performed by the other application.

Data fields can also be populated by direct communication with test equipment. The form displayed in Figure 2 is designed to automate testing. As the user clicks the colored test number fields the tests are run, and the appropriate data fields are automatically populated with the results.

TRENDING

PowerDB allows on-the-fly trending of any test point. Figure 3 shows an example of the trending presentation. Historical values for the particular equipment are shown in blue with connecting lines. All values for similar equipment are shown in red. A 2-sigma band is shown in green. The table above the trend chart lists all of the data values, as well as the test date and equipment location. Any record in this list may be selected to open the associated form with the detailed test results. This can be used to identify stray test values and review the test form to see what corrective actions were taken.

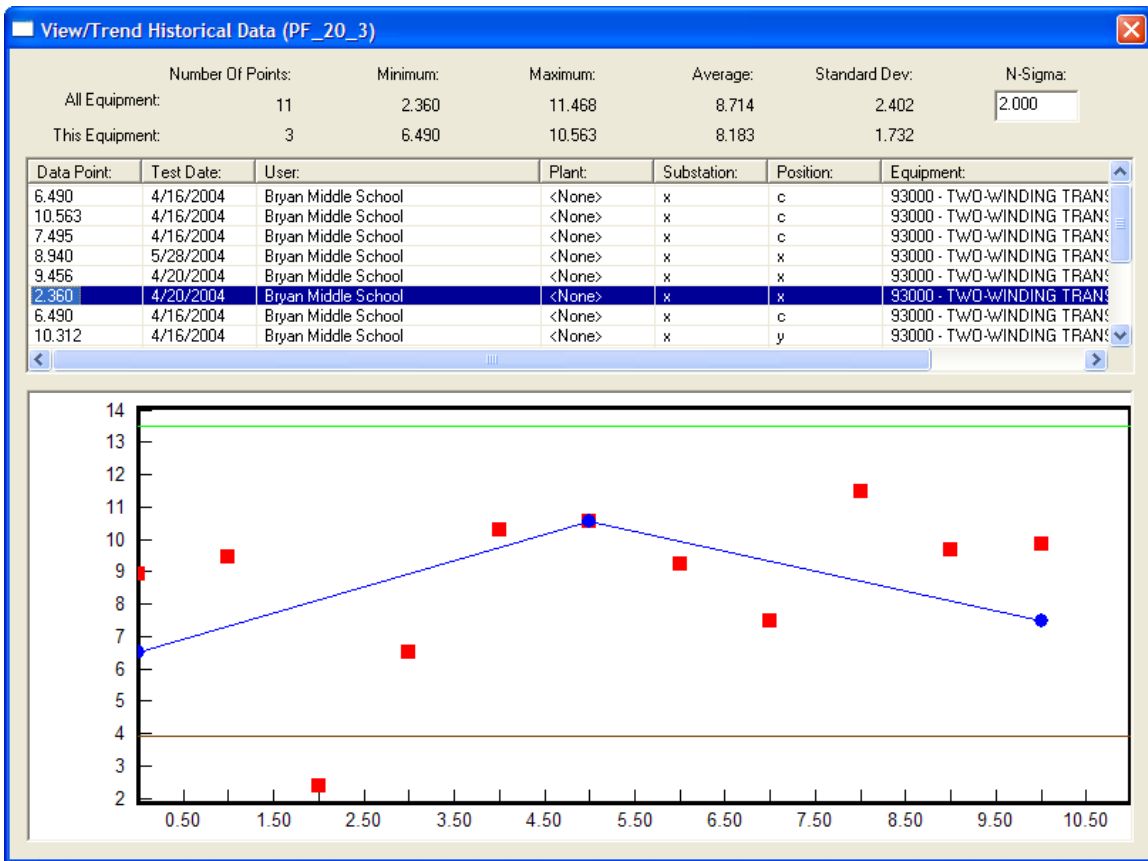


Figure 3: Trending (On-the-Fly)

Forms can also be designed to automatically display one or more trend charts of specific fields on the form. This provides an integrated presentation of all the current test information along with the trending of pertinent fields.

Future releases of PowerDB are planned to include programmatic analysis of data for trending purposes. This will allow particular fields on forms to be flagged for automatic trend analysis. The analyzed data will then be presented in trend analysis or failure prediction reports.

REPORT GENERATION

Report generation in PowerDB for a group of tested equipment is done in one step. Customizable sorting allows adjustment of the test form order. Forms can be suppressed and page numbering adjusted. Supporting reports, such as the comment and deficiency summaries, can also be selected for printing at the same time. All test forms and supporting reports are sent to the printer in a single print job. Figure 4 shows the results ordering and print dialog.

Typically, the report presentation of CMMS systems is poor. PowerDB allows the design of detailed and aesthetically pleasing test forms and summary reports. An example of a deficiency summary is shown in Figure 5.

In addition to generating reports directly through PowerDB, a web server is available which allows users to report on demand from anywhere. Only information pertinent to the particular web-access user is presented online.

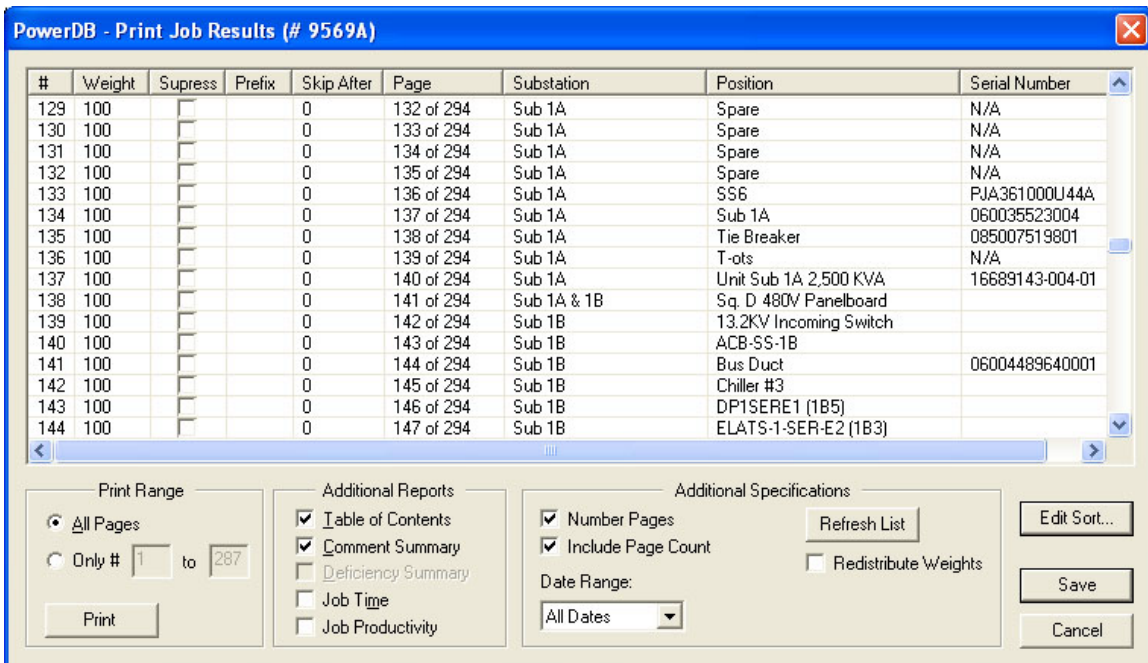


Figure 4: Results Ordering & Printing


	Deficiency Summary Job #:2001-0633		PAGE 1 of 1
	Customer <u>Electrical Testing Company</u> User <u>Woodlawn Hospital</u> Plant <u>Woodlawn Hospital</u>		
Substation: <u>M</u>		Position: <u>M3 MCC-E201</u>	
Equipment: <u>15000 - LOW VOLT. PWR. CKT. BKR. TEST</u>		Test Date and Time: <u>3/12/2002 2:46:26 PM</u>	
GROUND FAULT FUNCTION DEFECTIVE			Page 134
Substation: <u>M</u>		Position: <u>MAIN</u>	
Equipment: <u>15000 - LOW VOLT. PWR. CKT. BKR. TEST</u>		Test Date and Time: <u>8/7/2002 9:30:17 AM</u>	
THE BREAKER INTERMITTENTLY WOULD NOT CHARGE PROPERLY. INCIDENT OCCURED TWICE. RACKING THE BREAKER OUT AND BACK WOULD CORRECT THE PROBLEM. BREAKER CLOSING ON CHARGING CYCLE.			Page 135
Substation: <u>NA</u>		Position: <u>ELEVATOR DIST. PNL.</u>	
Equipment: <u>15600 - FUSE DISCONNECTED INSP. TEST</u>		Test Date and Time: <u>5/14/2002 9:31:32 AM</u>	
*** CONTACT RESISTANCE OUT OF TOLERANCE PER NETA SPECIFICATIONS. SWITCH IS DEFECTIVE.			Page 164

Figure 5: Deficiency Summary Report

DATA SHARING WITH CMMS

PowerDB has the capability of sharing data with CMMS systems. An interface to the Maximo system used by Texas Instruments in Dallas, TX was recently implemented. Any information on a test form, such as test date, nameplate information, serial number, and pass/fail status, can be passed to a supported CMMS system. There is also the capability of passing in a URL of the detailed test results to be generated by the web server. This allows a CMMS user to easily access many details about equipment that are not maintained in the CMMS system.

MEGGER AVTS INTEGRATION

The ability to design forms in PowerDB that can automatically access data in Megger's AVTS database has already been discussed in the section TEST

DOCUMENTATION. We propose two additional means of data sharing and presentation for PowerDB and AVTS.

The first is the ability for AVTS to generate XML output for each test, and for PowerDB to use this data in customizable reports. This would greatly enhance report generation speed in AVTS, and make it easier to share data with CMMS systems.

The second is to integrate a PowerDB reporting tab directly into the AVTS relay workbook. This would allow AVTS users to have enhanced reporting speed even without owning a copy of PowerDB.

CONCLUSIONS

The role of test documentation and data management is becoming increasingly important in identifying faulty devices and to document devices that are operating properly for liability reasons. It is essential that once a device is tested and identified as faulty that this device be formally tracked and rectified. Database technologies allow faulty devices to be identified using conventional test limits and can improve on conventional detection by utilizing trends and variances to identify possible future failures.

A relational database is an ideal tool for managing and analyzing preventative maintenance test results. It allows data trending by accessing the historical results for a particular piece of equipment and the results of similar equipment. Data trending can be presented graphically and analyzed programmatically. A relational database of preventive maintenance test data also allows the possibility of reporting test results for particular locations and work-orders, of programmatic data analysis, and of summary reports.

Typically, an organization uses several software packages for testing equipment, collecting and reporting data. The cost of maintaining these individual “islands of automation” prohibits effective analysis and integration with CMMS systems. Through manual data entry, data imports, instrument control, analysis, reporting, and CMMS interface, PowerDB is a unifying solution to this problem.