g systems

Using LabVIEW™ to Monitor Underground Electrical Distribution Vaults in Dallas, Texas

NIWEEK™ award winner

TU Electric must monitor the condition of the underground High Voltage electrical distribution vaults in downtown Dallas. G Systems, a LabVIEW systems integrator, used LabVIEW and National Instruments hardware to acquire the signals from 30 different communication lines, check the conditions in 276 vaults using LabVIEW signal analysis VIs, and make the conditions available at a glance on any one of 96 different user selectable maps of downtown Dallas.

The Challenge

Monitor the condition of the electrical distribution vaults in downtown Dallas, Texas for dispatch of repair crews.

The Solution

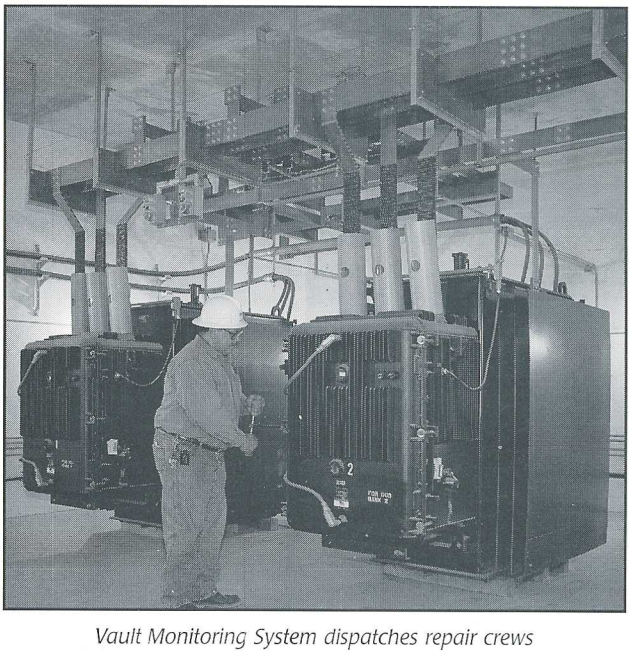
Use LabVIEW to create a program with a user interface that shows the condition of all vaults at a glance overlaid on city maps.

Introduction

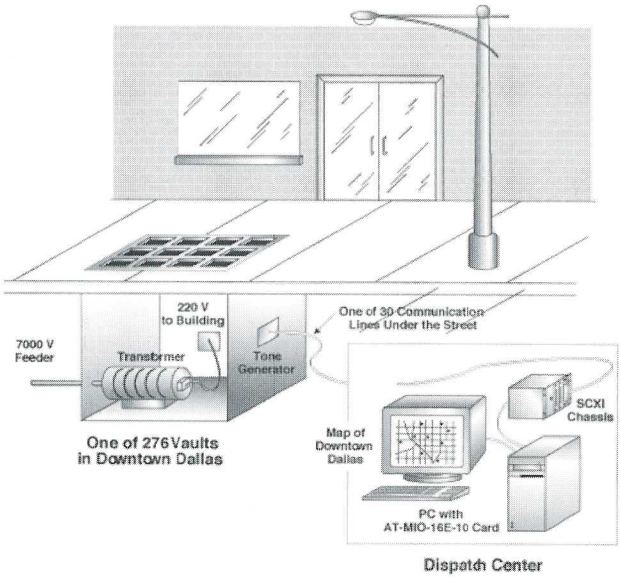
As in all large cities, the electrical distribution transformers and circuit breakers in downtown Dallas, Texas are in underground vaults beneath the city sidewalks. Vaults can flood after a heavy rain, circuit breakers can open, or the transformers may overheat requiring crews be dispatched to correct the problem. In Dallas, the 276 vaults are monitored at the TU Electric dispatch center in downtown Dallas. Alarms are transmitted as audio tones over thirty communication lines buried under the streets. The communication lines are over 70 years old, protected by inch thick lead sheaths, and were originally used to communicate with work crews out on the street. When splices are made, the date is impressed in the lead. The communication lines have splices going back well over half a century, including one marked December 5, 1941.

Each vault has one or more audio tone generators. Each tone generator is connected to one of the 30 communication lines and assigned one of the 26 frequencies between 420 Hertz and 3420 Hertz spaced every 120 Hertz. Under normal circumstances (no alarm) each tone generator continuously transmits a tone on its assigned frequency. If there is an alarm (such as a flooded vault), the generator shifts its tone up or down in frequency by 30 Hertz. Thus, each tone generator can transmit only one of two possible alarm conditions, and a vault with a single tone generator can be monitored for two types of alarms (for example, vault flooded and transformer overheated).

At the dispatch center, TU Electric has a 30 year old system for checking for alarms. The old equipment scans each of the 30 communication lines with a microphone listening for either a missing tone (which indicates the tone generator in the vault has broken down or there is a break in the communication line) or a tone at a frequency that indicates a alarm. The addresses of all 276 vaults in downtown Dallas are shown on a CRT display. When there is an alarm, the monitoring equipment highlights the address of the vault. To check for alarms, a user has to scroll through the list of addresses looking for highlighted entries.



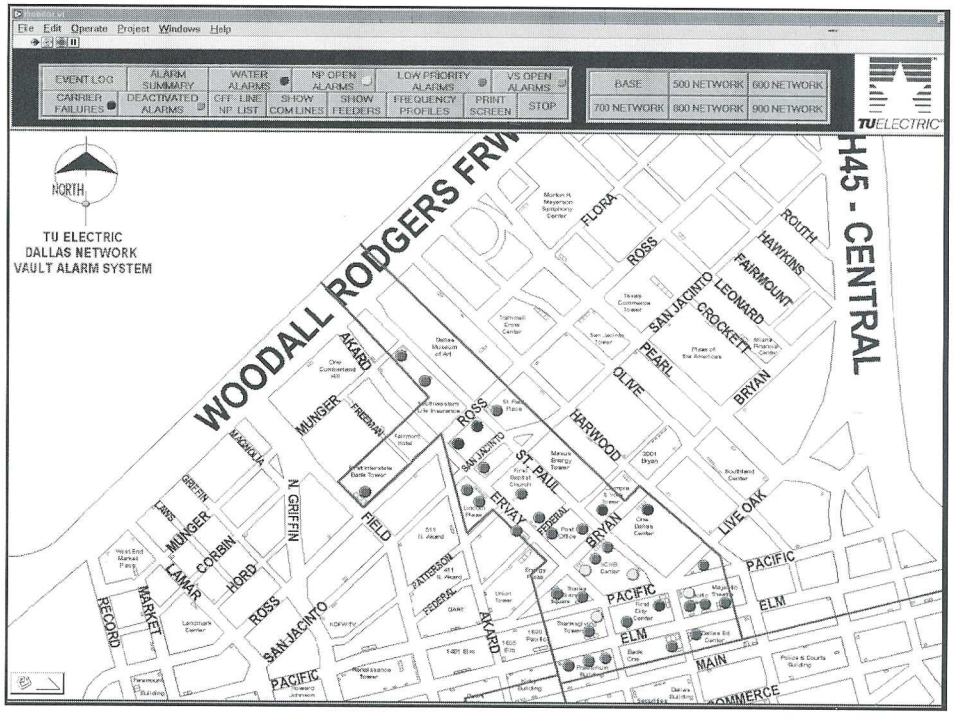
Vault Monitoring System dispatches repair crews



In downtown Dallas, the condition of each electrical equipment vault (for example, vault flooded) is coded as an audio tone and transmitted to a central dispatch center via communication lines buried under the streets. At the dispatch center, the monitoring system displays the condition of all 276 vaults on a map of downtown Dallas.

Upgrading the Vault Monitoring System

TU Electric wanted to keep the old monitoring equipment in the vaults. However, they contacted G Systems to change the way the vault alarms are checked at the dispatch center, how alarms are displayed, and the amount of information about the vaults available to their service personnel. TU Electric wanted a display built around maps of downtown Dallas with a dot at the location of each vault. There should be one overview map showing all of downtown Dallas, 5 detailed maps each showing a different part of downtown, a map for each of the 30 communication lines, and a map for each of the 60 High Voltage feeders supplying power to downtown (96 maps altogether). On any map, the color of a dot would show the condition of the vault at that location. Clicking on a dot would bring up a new panel with detailed information about the electrical equipment in the vault. The user had to be able to edit the information on this last panel at any time. There needed to be a log for each type of alarm giving the vault location and the date and time the alarm was recorded. Finally, the new monitoring system must be able to run unattended for weeks or months on end, be modifiable to include new vaults, new tone generators, and new electrical equipment, and meet budgetary constraints.



Front panel of the TU Electric vault monitoring system showing a map of part of downtown Dallas. Vault locations are marked with dots. The color of the dot gives the condition of the vault: red is normal, blue is flooded, yellow is network protection open, and black is no signal from the vault.

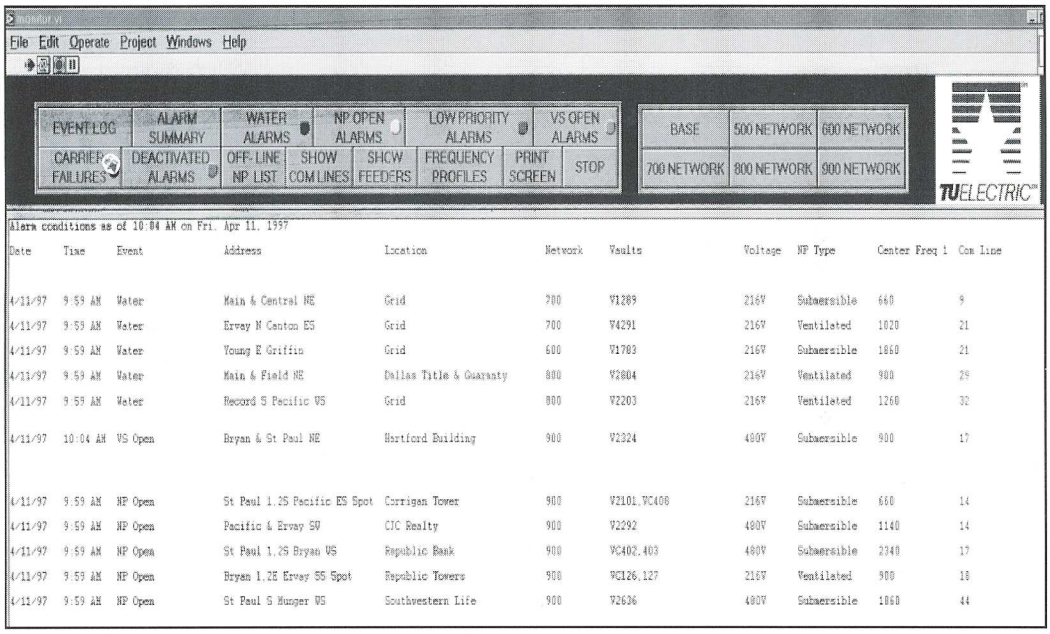
How The New Monitoring System Works

G Systems used LabVIEW 4.0.1 running under Windows 95 and National Instruments data acquisition hardware. With LabVIEW, we knew we could write and debug the monitoring software quickly, but, more importantly, we knew that with LabVIEW, we could build the complicated graphical user interfaces, such as the maps, toolbars, and interactive data displays that TU Electric wanted.

We use an SCXI-1000 chassis with two SCXI-1122 sixteen channel analog input modules to acquire and filter the signal from each of 30 communication lines, and an AT-MIO-16E-10 to sample and digitize each signal. The communication lines from under the streets come out of the wall next to the SCXI chassis and go straight into the SCXI modules for signal conditioning.

The software has two main tasks: 1) a task to analyze the data and update the maps , and 2) a task to manage user interactions. Each task runs as a separate loop in the main LabVIEW application.

The first task loop handles alarms. The vault monitoring system finds the power spectrum of the data from each communication line

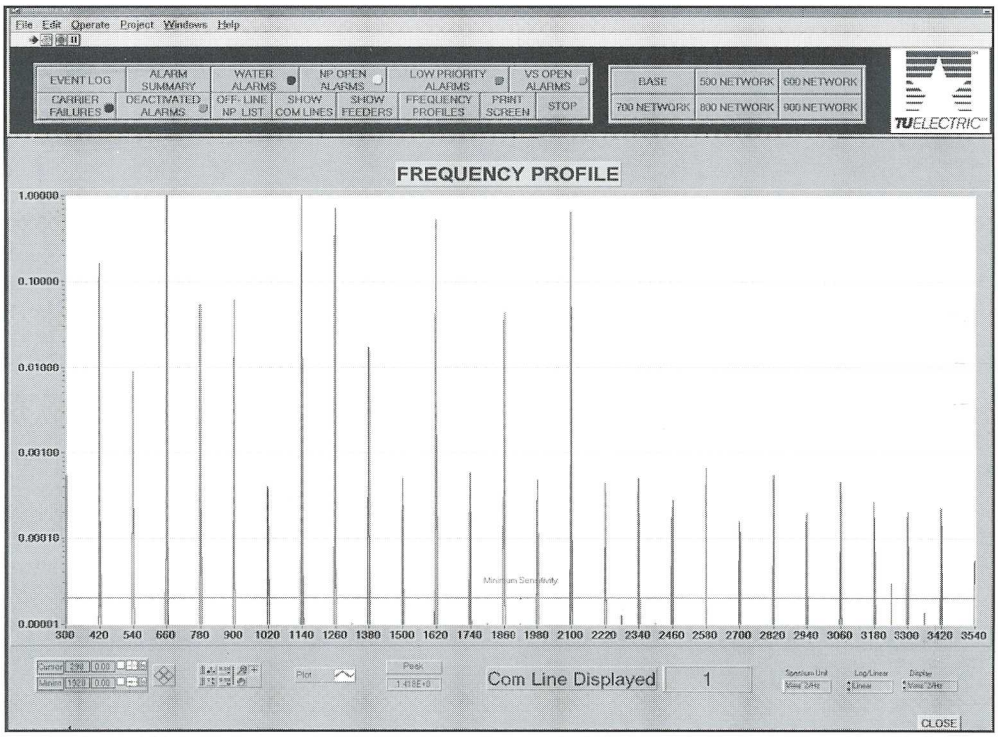


The vault system records a log for each alarm giving the vault location, and the date and time the alarm was recorded.

writing the new color of the dot at the vault location to a global variable. All maps read this global variable and make changes in dot colors if necessary.

The second task loop handles events from the user interface. There are two tool bars. One allows the user to show the overview map of downtown Dallas or one of the five detailed maps. The second toolbar allows the user to open the alarm logs, the communication and feeder maps, look at the power spectrum of any of the 30 communication lines, or print what is currently displayed on the screen (either a map or a log). The

using LabVIEW analysis VIs, looks at each frequency where a 'no alarm' tone should be, and checks for a signal above the noise floor. If nothing is found, the system looks for a signal at either of the two frequencies where alarms occur. If a signal is found, the system checks a file to see what kind of alarm corresponds to that frequency. If there is still no signal, the tone generator or the communication line has failed. This is important information and is recorded. If there is a new alarm, or the signal from a vault has been lost, then the maps and logs must be updated. The vault monitoring system updates the appropriate alarm log by writing the time, date, and vault location to an alarm log file that can be accessed on the TU Electric intranet. The LabVIEW application updates the maps by



A sample of the many report options provided to the user.

96 different maps presented a problem. All maps were created in a CAD program, put on the clipboard, and pasted onto the front panels of 96 separate VIs. Each VI is about 2.2 Megabytes. The six most commonly used maps (the overview and 5 detailed maps) are loaded into memory when the program starts and kept there. The other 90 maps for communication lines and feeders are used much less frequently and are loaded when needed and unloaded when closed using the VIs in the VI Control Palette.

Conclusion

LabVIEW allowed us to quickly build and debug a vault monitoring program with a sophisticated user interface. The new vault monitoring system shows the state of all 276 vaults at a glance, as TU Electric wanted, and additional information is easy to access. Using the new system requires very little training. TU Electric dispatchers can print out summaries of alarm lists and maps on the spot for work crews. In the future, dispatch crews will be able to read the alarm logs in the field using radio modems and laptop computers. Using NI hardware resulted in a system with two orders of magnitude better sensitivity than with the old equipment. Signals from vaults that had been lost in noise for years suddenly appeared. An added and unexpected bonus of using LabVIEW was that one of the TU Electric engineers learned enough about LabVIEW from watching G Systems programmers at work and asking questions, that he can make changes to the application such as adding new vaults or map changes himself. Future plans are to possibly adapt this monitoring/dispatch system in other areas of the country where frequency-tone monitoring systems are used.

Products used

LabVIEW
DAQ
SCXI

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