Locating Faults in Urban Underground Vaults at CFE

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***Abstract*—The 23 kV underground electric network of historic downtown Guadalajara has been operating for more than 40 years. Some of the aging equipment is failing. These failures are difficult to locate because the underground electrical vaults are difficult to access, disrupting increased vehicle and pedestrian traffic. This paper describes the solution by Comisión Federal de Electricdad, who successfully installed a wireless underground fault indicator system.**

I. Introduction

Comisión Federal de Electricidad (CFE) División de Distribución Jalisco (DDJ) pioneered installation of the underground distribution network in Mexico in the 1960s. Now, with a system over 40 years old, it is difficult to locate faults due to increased vehicle and pedestrian traffic in Guadalajara. Currently, the city has more than 4.5 million inhabitants and more than 1.6 million vehicles.

During the year, at least one out of four distribution circuits typically fail during the rainy season (June through October), causing the loss of important energy loads to such areas as the State Congress buildings, state and municipality government centers, hospitals, and traffic signals. These outages seriously affected the daily functions of these work areas and created chaos on the roads.

These failures mainly affected four 23 kV underground distribution circuits of the Alameda Substation: 5115 Teatro Degollado Circuit, 5125 Hospicio Circuit, 5175 Juan Manuel Circuit, and 5185 Ocampo Avenue Circuit, as shown in Fig. 1.

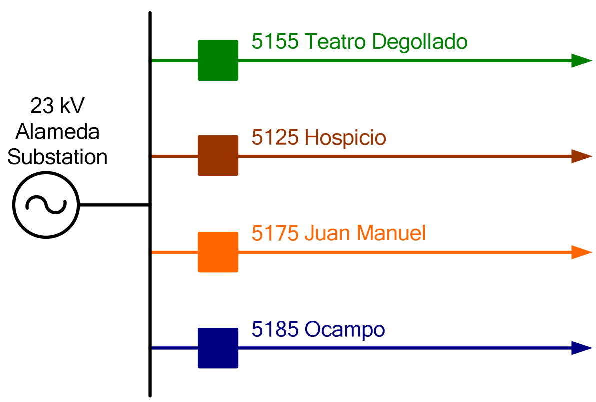

Fig. 1. One-line diagram of the 23 kV Alameda Substation [1]

At that time, the method used by CFE personnel to locate failures was to send crews to open each of the underground vaults and inspect the conventional faulted circuit indicators (FCIs). If a crew confirmed that a fault current passed through the circuit, the next vault would be checked, and so on, until the faulted circuit was traced and repaired.

This tedious and labor intensive method created risk and danger for the CFE workers because of the vaults' locations. Most vaults in this system are located in busy streets with pedestrian and vehicle traffic. Additionally, the crews may encounter vaults filled with water or vermin.

Due to these obstacles, fault location was slow and difficult, resulting in high costs for the utility. Using this method, CFE spent an average of 1.75 hours to locate a fault.

CFE determined that this situation did not meet their quality standards. They decided to invest in a new technology to provide an economic, fast, and reliable method of fault location.

After analyzing technologies from different manufacturers, CFE decided on a simple and economical solution: to implement and install FCIs with wireless communications capacity, using a wireless communications interface where the FCI and a wireless remote reader are connected. This system is also capable of showing the FCI state (tripped/normal) in real time.

II. System Implementation

CFE evaluated different technologies and methods of indication and fault location for underground distribution networks. The goal was to find a system to accomplish the following requirements:

1. The FCI should be standard throughout the network, using one indicator type or model to simplify inventory and facilitate replacement.
2. The FCI state indication should be wireless transmission; the antennas should be inside the vault, providing a hands-free frequency with radio transmission distance not less than 20 meters from the vault center. The objective should be to read the state of each FCI without physically accessing the vault and without stopping vehicle traffic.
3. The state indication device of the FCI should show both states (tripped/normal) of each FCI installed inside the vault. This device should be compatible with all of the FCIs installed in the vaults.

The option selected was to install an FCI that is automatically adjustable (50 to 1200 A) in the field to perform the circuit load current measurement, using a predetermined value to recognize a trip. To accommodate future load growth and additional circuits, CFE selected an FCI that can automatically adjust to the new operating conditions. This flexibility allows CFE to use only one type of FCI for all the underground network points. This standardization makes replacement easy and satisfies Requirement 1. See CFE installation as shown in Fig. 2 and Fig. 3.

Fig. 2. CFE crews install fault indicators and wireless interface units in Guadalajara vaults

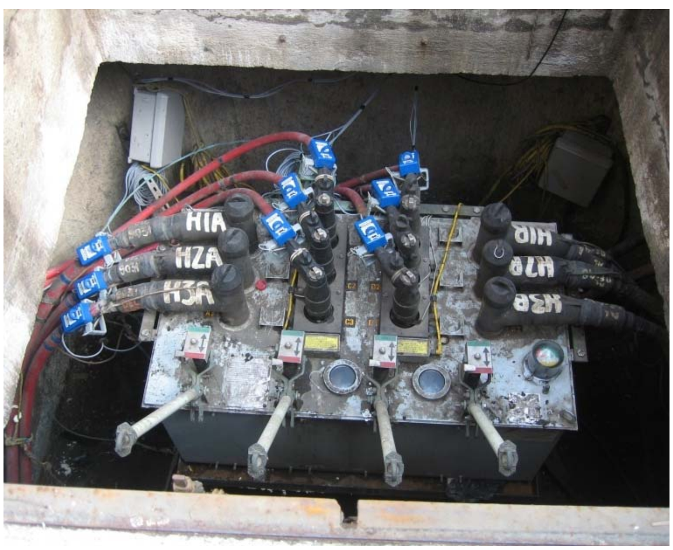

Fig. 3. Fault indicators installed in Guadalajara vaults connect to wireless interface units to communicate fault passage information outside of the vaults

These FCIs are safe and secure because their status is transmitted to a wireless interface (WI) via a magnetic interface; no direct electrical connections are used. Then the WI transmits the real-time status of the FCI (tripped/normal) at 900 MHz when requested by a hand-help remote fault reader. It also includes a remote antenna installed inside the vault, which proved to operate and reach data transmission ranges between 25 and 35 meters. This performance met Requirement 2. The WI is shown in Fig. 4.

Fig. 4. Wireless interface with antenna and magnetic FCI connections

The WI collects and communicates the status and data by a remote fault reader, which shows the FCI real-time state through a lighted LED interface:

Normal FCI = Green LED On

Tripped FCI = Red LED On

The WI state and identification are shown in Fig. 5.

Fig. 5. Remote fault reader

The installation included 639 faulted circuit indicators and 61 wireless interface systems to cover the 4 distribution circuits of the Alameda Substation, as shown in Fig. 1 and Fig. 6. It included 14 remote fault readers.

CFE also identified the need to train both the engineering staff and the troubleshooting crews on the benefits, performance, and use of the wireless fault indication system. Training maximized system performance and user experiences because the engineers and crews knew what to expect from the wireless fault indication system, as well as how to install and operate it.

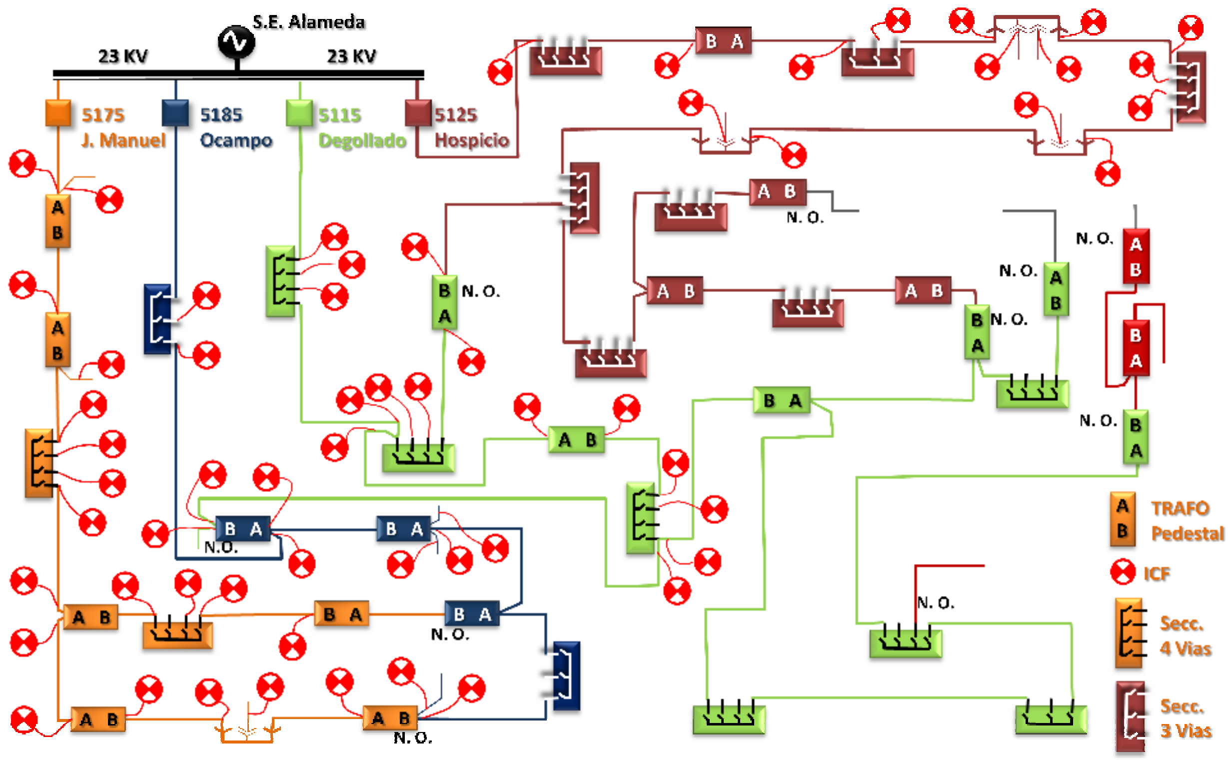

Fig. 6. Underground network topology [2]

III. RESULTS

The performance and efficiency of the new underground network locating fault system of Guadalajara has been tested three times with actual faults. Each time, the system correctly identified the fault.

A. First Fault

The first fault detected by the system happened on March 17, 2008, at 8:57 a.m. The location was at Prisciliano Sánchez and Colón Avenue on the 5115 Teatro Degollado Circuit of the Alameda Substation in the AJ 9014 transformer. A backhoe used by municipal workers caused this fault during an excavation. The damage to the underground system resulted in a three-phase fault. Repair crews used the fault reader and detection system to correctly detect, locate, and identify the fault in 55 minutes.

B. Second Fault

The second fault detected by the system happened on June 2, 2008, 12:41 p.m., when a fault appeared at the 5185 Ocampo Avenue Circuit of the Alameda Substation. A damaged junction failed between Pavo and Prisciliano Sánchez Street. The fault was detected and identified correctly by the fault reader and detection system. It took only 50 minutes to locate. In this case, the vault was difficult to find because it had been covered with asphalt by the City of Guadalajara.

C. Third Fault

The third fault detected by the system happened on October 9, 2008, at 1:44 p.m. on the 5185 Ocampo Avenue Circuit of the Alameda Substation. The AJ-9033 transformer located on Miguel Blanco Avenue and Pavo Street failed. Repair crews used the fault reader and detection system to correctly detect, locate, and identify the fault in 44 minutes.

IV. CONCLUSIONS

The fault reader and detection system implemented by CFE showed four clear benefits to the utility and its customers. The new system:

- Considerably reduces the fault-finding time up to 50 percent without the need to enter a vault
- Reduces the size of troubleshooting crews
- Improves the fault-finding process because street and pedestrian traffic are not interrupted
- Improves safety because CFE crews do not need to take risks entering vaults and pedestrians no longer risk falling into an open vault

V. REFERENCES

[1] Comisión Federal de Electricidad, One-Line Diagram of the Alameda Substation, September 2008.

[2] Comisión Federal de Electricidad, Diagram for the Implementation and Location of Faulted Circuit Indicators, December 2007.

VI. BIOGRAPHIES

José de Jesús Borrayo Sánchez graduated as an Electrical Engineer, Power Specialty, from Technological Institute of Tepic in 1992. In 1993, he started work at Comisión Federal de Electricidad División de Distribución Jalisco as a Distribution Supervisor in the Hidalgo area until December 1995. From 1996 to 2006, he worked as Protection Divisional Supervisor and was promoted as Department Chief of Distribution Area of Guadalajara in 2009.

Juan Manuel Farías Garibay graduated as a Mechanical Electrical Engineer from the Guadalajara University in 1992. Starting at Comisión Federal de Electricidad (CFE) in the same year, in the Jalisco Distribution Division, he worked as a Construction Supervisor of the Underground Network Office in the Guadalajara area and as Division Distribution Supervisor of the Offices of Hydraulic Maintenance, Electric Maintenance, and Circuit and Network Maintenance. He also acts as a coordinator for the Underground Distribution Network and Lines National Committee, participates in the Technical Norm of Labor Competition, and provides training to the distribution engineers of the Jalisco Division. He has contractor certification, is an instructor at the National Training Center of CFE, and belongs to the specialists group for updating the Distribution Norms—Underground System Construción.

Gerardo Urrea Grijalva earned his bachelor of Electrical Engineer degree, Power Specialty, from the Technological Institute of Hermosillo in 1997. He became a Scholar in Training at Technological Research (AIT), Electrical Research Institute (IIE), in the Simulation Department (URS). In 1997, he started to work in the CFE Northwest Division in the Project and Construction Division. From 1997 to 2001, he held the position of Substation and Lines Construction Supervisor. From 2001 to 2003, he worked in CFE Guaymas area as a Protection Supervisor. In 2003, he started to work at Schweitzer Engineering Laboratories, S.A. de C.V. as a Protection Designer Engineer. The following year he was promoted to Technical Support Center Engineer. In 2005, he was promoted to Sales and Technical Support Manager of the North and West Regions of Mexico.

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