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REMOTE MONITORING OF INCIPIENT FAULTS USING GPRS IN POWER TRANSFORMERS

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Abstract − One of the most applied procedures for detention of incipient faults in power transformers, such as partial discharges, electrical arcing and overheating, is the analysis of the concentration of gases dissolved in the isolating mineral oil. This analysis usually is carried through in a laboratory through chromatography in gaseous phase. Although it presents trustworthy results the chromatography brings some inconveniences as the need of a periodic sampling along with the distance from the laboratory to the substation of electric energy. There are some measurement systems available with the capacity to carry through this analysis in the field. However these devices are costly, not justifying its use in a dedicated form in low cost power transformers. In such a way, a project for the monitoring of multiples transformers was initiated using only one measurement system. One of the most important features of the developed equipment is its capability to remote control and monitor. Thus, an Internet procedure based in GPRS (General Packet Radio Service) technology was developed. The use of the GPRS for remote communication made possible the development of an equipment more independent, capable to transmit and receive commands from different substation of electric energy.

Keywords: gas dissolved in oil, GPRS, power transformer.

1. INTRODUCTION

Power transformers are essential equipment in the transmission and distribution of electricity and therefore deserve special attention in the maintenance program of the electrical companies.

One of the most important parts of the transformer is the insulation system, which consists basically of a liquid, usually mineral oil, and a solid insulation, the insulating paper.

During operation of a power transformer, the mineral oil is subjected to the actions of temperature and electrical stress, suffering chemical decomposition processes that result in the formation of gases.

The gases formed by decomposition of insulating materials are partially or totally dissolved in the oil, being diluted and transported throughout its volume. This decomposition is more intense when there are failures in the operation of the transformer, like the presence of partial discharges, electrical arcing and overheating.. The dilution of the gas allows one to obtain, through the analysis of a sample, information about the deteriorating state of the various points that are in contact with the mineral oil [1].

Therefore, the analysis of dissolved gases is one of the most established procedures for detecting faults in power transformers. Such analysis is commonly performed in the laboratory by gas chromatography. Although it presents reliable results, the chromatography has some drawbacks such as high sampling period and the long distance of the laboratory related to substations.

There are measuring systems able to perform the analysis in the field, determining the concentration of specific gases dissolved in oil. However, these devices present high cost that does not justify its use dedicated to a small transformer. Thus, a project for remote monitoring multiple transformers with a single measurement system was started. Tests of feasibility were performed and later a prototype was built. The new equipment was named MAGO (from the Portuguese, *Múltiplo Analisador de Gás em Óleo*, Multiple Gas-in-Oil Analyzer).

2. PRODUCT DEVELOPMENT

For the analysis of the oil of power transformers it has been developed portable equipment capable of performing the multiple sampling of up to three transformers.

This multiplexing is performed by the actuation of electrical valves that release the flow of oil from the transformer one wish to examine, as seen in Fig. 1. Two three-way valves (A and B) are responsible for multiplexing and the others (T1.2, T2.2, T3.2, T1, T2, T3 and D) are responsible for releasing the flow of oil.

In Fig. 2 can be seen the prototype equipment performing the analysis of a transformer at the power substation of Coqueiros from Celesc, a company of Brazilian electric sector.

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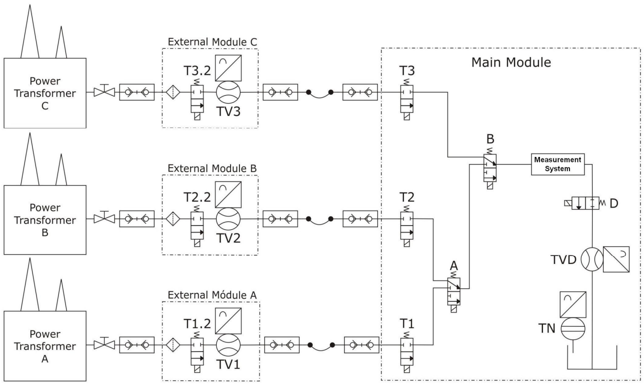

Fig. 1. Hydraulic diagram [2].

The electrical system developed, together with the use of a sophisticated PLC, is responsible for controlling and monitoring the electrical valves, gas meter, flow transducer and other features of the equipment.

Fig. 2. Gas analyzer in operation [2].

Fundamental part in the operation of the equipment is the communication with the user. It was implemented two basic forms of operation, one for the user in the substation (local communication) and another for the remote user (one far way from the substation).

It was developed two forms of remote communication, one connecting the equipment directly to the Internet and another using the mobile telephone network via GPRS.

3. LOCAL COMMUNICATION

The local communication is performed by a physical interface for operation of the prototype in the substation. By means of buttons the user sends the desired command to the PLC. The PLC performs the commands received and signals the user the valves activated, the active mode of operation, measurement in progress and alarms, leak and level of oil reservoir.

The Fig. 3 shows the local control interface developed for MAGO.

Fig. 3. Local interface panel of MAGO.

4. REMOTE COMMUNICATION VIA INTERNET

Access to equipment is accomplished via the Internet through a network cable plugged directly into the controller. The transmission of data inside the patio of maneuvers is performed via optical fiber, making it immune to electro-magnetic interference.

To the PLC is assigned a fixed IP address within the network where it is installed. An HTML page, hosted in the controller, is responsible for interfacing with the software loaded. Thus, the user can operate the equipment from any computer that has access to the same network.

5. REMOTE COMMUNICATION VIA GPRS

Although it brings a range of facilities, communication via the Internet is subject to availability of network access to computers at the site of installation. Most of the substations from CELESC (Power Company for which the equipment was developed) lacks the access to the internet.

In order to circumvent this problem it was developed a communication system through GPRS (General Packet Radio Service).

GPRS is a service implemented on the structure of GSM (Global System for Mobile Communication), which uses, for the management of resources, a combination of two techniques, the TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access).

GPRS is a service offered by mobile operators to increase the GSM network by including the method of switching of packets in order to transfer data [3].

Unlike the method of switching circuits, employed by previous technologies, in a packet switching resources are shared and only allocated when the data is transferred. Thus, it can be argued that users are always connected, receiving the resource only on the time of sending and receiving data [4][5].

The GPRS is connected to the internet through a Gateway WAP (Wireless Application Protocol), which is an international standard for applications that use wireless communication [6][7].

In order to implement this technology in the analyzer of gas dissolved in oil, uses a GPRS modem that has a serial interface RS-232, enabling communication with the PLC.

Due to its characteristic of being "always connected" to the GPRS network, mobile phone companies have to deal with a limited number of available IPs. The solution was found by giving the addresses dynamically. With dynamic IP a user lose their addresses to the connected devices when they remain idle for a certain period of time, getting them again in random way through DHCP.

The policies adopted by the mobile phone companies significantly increase the difficult to applications that use this technology, since a priori it is impossible to locate a mobile device inside the network. Consequently, the initiative to connect from a remote device always points to a fixed location. This would difficult to keep track of equipment from various locations, restricting the supervision local of a single point.

The solution adopted was to develop a server with a static IP, which the modem always tries to establish a GPRS connection. Thus, after the connection done, the location of the equipment is not unknown, at least until the next renewal of their IP, when the process has to be done again.

The inclusion of a centralized server provides a topology modular communication system, which decoupled the system interface, thus enabling a wider range of supervisors of operation (Fig. 4).

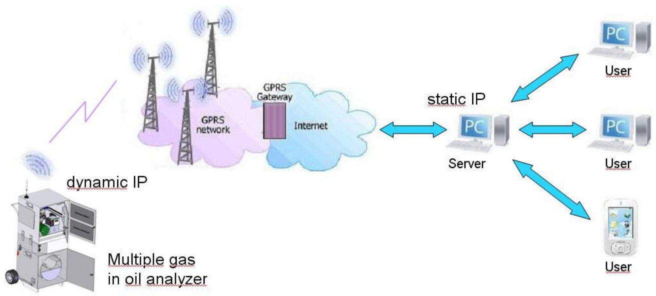

Fig. 4. Topology of the communication system via GPRS.

Internally, the server was also developed with a modular architecture, doing communication with the MAGO and the operator independently of each other, as seen in Fig. 5.

During the measurement process the server receives the partial results and updates its internal database. Thus, even if the measurement has not finished, the data for measurement are properly stored. With this topology the user does not need to stay connected throughout the measurement process. The data stored on the server are passed to the user when it connects to the server.

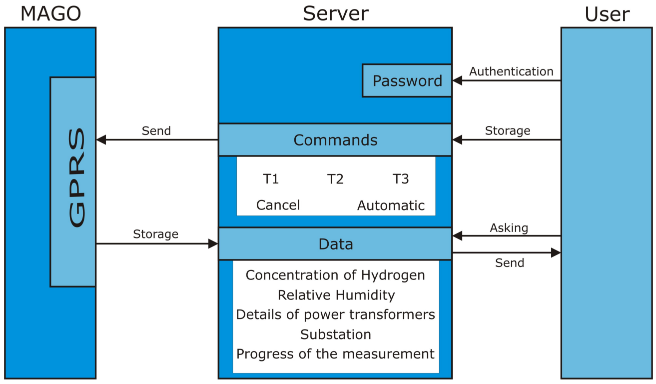

Fig. 5. Communication between MAGO, Server and User.

The server was developed on the object–oriented paradigm, using Java programming language, with the possibility of operate on any operating system that has compatibility with the Java virtual machine.

The mechanisms of sockets based on TCP service, protocol for data transfer, were used for communication between points. The TCP, connection-oriented service, provides a reliable transport mechanism bases on exchange of Acknowledgments with retransmission in case of loss.

The functionality of the server is based on concurrent programming, using the resources of multithreading. The two clients in the communication, MAGO and user, access the server by mutually exclusive gates, each connection administered by a specific *thread*.

In connection with the remote device, the traffic information in both directions can occur on a competiting way, as is the MAGO who decides the time for transmission of information. In order to make this possible there are two additional *threads*, one responsible for sending and another for receiving information.

In case of inactivity in the flow of information (for approximately 2 minutes) the phone company purposely ends the connection. Ahead of this, the server has a timeout mechanism at the reception that terminates the connection and the Threads involved and then awaits the new connection from MAGO.

In the process of interaction with the user there is no need to send and receive data simultaneously, since the interface is configured to request data, which are immediately passed to the user by the server. That means the server does not send data to the user in a standalone mode, it only responds to requests.

A basic class on the server, called “table of storage”, is responsible for storage of data related to the process of measurement. This class is responsible for all handling of data circulating between Threads of flow of information. The storage is done in two ways: dynamically through variables allocated in volatile memory and statically through periodic written in a file saved on hard disk. This mechanism aims to protect data stored on the server in case of failure in the equipment where it is installed.

6. SOFTWARE CONTROL

When the request for access is made via Internet, the software that access MAGO triggers the browser directing it to an address in the format:

http:// "PLC's IP" / "name of the application.".htm

.

With this address the user has direct access to the software loaded in the PLC.

In the main panel of the software interface board (Fig. 6), below, the user has the ability to:

• Perform a manual measurement of the concentration of dissolved gases and moisture in the oil of transformers connected to the equipment;

• Set the measurements to be performed automatically;

• View the operation of solenoid valves, the current mode of operation, alarms and remaining time of measurement and drainage;

• Follow the values of the measurement system of gas concentration and moisture, the flow transducer and the oil level in the reservoir.

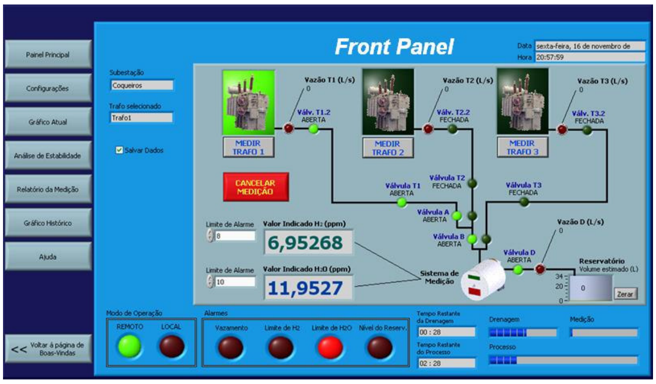

Fig. 6. Panel of leading software command.

In addition to the main panel, the user can access through a menu, other features of the software, such as:

• information from transformers that are connected to the equipment and the substation where it is installed;

• change settings of the software;

• show a graphic of the current measurement of the concentration of hydrogen in the oil and moisture;

• view a report of the last measurement;

• submit a report via e-mail (the default setting is the automatic transmission after the end of measurement);

• view the history of measurements for each transformer that has been monitored by the equipment, specifying the time interval of interest;

• show a help page in order to operate the software.

7. CONCLUSIONS

The use of the analyzer of gas dissolved in oil helps to prevent critical failures of power transformers due to more effective monitoring of their conditions during operation.

The use of MAGO rather than eliminate costs from the collection and transportation of the oil to be analyzed, but increases the reliability of the representativeness of the samples. The removal of the sample in an automated manner may avoid errors during normal manual sampling. Moreover, the speed of measurement after removal of the oil reduces the risk of considerable changes in the concentration of gases dissolved in the sample.

The use of flow transducers for determining drained volume provides a considerable reduction in the collected oil required for each sample. The volume of the oil used for a measurement implemented by the MAGO is approximately 452 milliliters, while the traditional method, gas chromatography, uses approximately 2 liters.

Furthermore, the interval of time between one analysis and another is reduced significantly using the MAGO, when compared to the time required for sampling and analysis in gas chromatography. The time required for each analysis depends on the response time of the used measurement system.

The portability of the design obtained in the MAGO helped adapt it easily to other transformers and substations that were not originally designed for such device. The issue of portability also enables the monitoring of critical transformers regardless of the purchase value of them, including those of smaller size which does not justify the investment of a dedicated monitoring system.

The use of MAGO in substations does not replace the chromatography, but works with it allowing a periodic sampling. Thus its use maximizes the efficiency of chromatographic tests using the better of the two processes: the quality of results obtained with the laboratory method and the speed, multiplexing and low cost of the results obtained with the MAGO.

The developed communication via GPRS enabled the autonomy of remotely accessing the equipment, proving to be a viable alternative, with low cost, which can also be used in monitoring other devices.

It is suggested to continue this project with the aggregation of new measurement systems for monitoring of different quantities equally important in the assessment of power transformers. Furthermore, modifications such as the miniaturization of the equipment to enhance its portability and the association of oil regeneration systems, should be considered.

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