MONITORING DEVICE FITTED ON-BOARD A MV CIRCUIT-BREAKER, IN REMOTE AS WELL AS LOCAL ACCESS

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ABSTRACT

Medium voltage circuit breakers are designed to require less and less preventive, systematic maintenance and have reliability levels which are improving from generation to generation, gradually reducing the risks of failure. However, increasing economic constraints in all business sectors mean requirements for availability are also increasing and the occurrence of faults is becoming increasingly unacceptable.

Indeed, by providing "protection against electrical defects", the MV circuit breaker plays a key role in the electrical network, meaning that any failure can have serious consequences in terms of the safety of people and property as well as in terms of economic, financial and even social aspects.

If we also consider its long life cycle – 20 or 30 years – having permanent visibility of the working condition and any change in performance levels over time has become a necessity in order to plan ahead and avoid any unpleasant surprises.

Knowing the device’s working condition involves:
- knowing the operating conditions (auxiliaries voltage, ambient temperature, etc.)
- being able to monitor the change in characteristic behavioral values over time
- being capable of detecting any possible deterioration in functions at a sufficiently early stage.

The focus on lower maintenance costs, combined with developments in techniques allowing us to automate in many sectors, has led to a strong reduction or even elimination of staff in electrical installations. Control and monitoring of electrical networks is increasingly carried out using centralized supervision systems, and the emergence of NITCs, including WEB technologies, is playing an increasingly major role in managing equipment and systems.

In this article, we present a device that is fitted on-board a medium voltage circuit breaker that allows us to monitor its operating conditions and we then go on to propose a system for the transfer and processing of data, using the most advanced techniques and technologies. The purpose is to improve the availability and therefore the technico-economic performance of the electrical network.

INTRODUCTION

With changes in the market, utilities companies are confronted with 2 increasingly strong demands:
- The need for maximum power availability
- Minimizing of their costs.

In order to meet these demands, they have had to reassess the management strategy of their equipment base at each stage in its life cycle:
- Initial investment,
- Incorporation
- Operation
- Maintenance
- Technical upgrading
- End of life recycling

Although the equipment has high reliability, maintenance costs and loss of operating use remain a major item in expenditure that can be significantly reduced with the appropriate policies.

The ability to anticipate device failure is part of this policy. This can effectively be anticipated by monitoring equipment condition, achieved by collecting and providing a set of relevant parameters, in the appropriate time and place.

Equipment and systems must therefore develop in order to allow an increasing amount of data to be collected and processed, without interrupting service, and making this data easily available to a large number of players. This development also concerns the associated user-machine interface functions, which must notably take account of lower maintenance staffing levels.
This article presents an applicational example of this development in monitoring a medium voltage circuit breaker.

It describes a device which will enable on-line collecting and monitoring of parameters to indicate that the device is in good working order, and then goes on to describe the way of transmitting and then processing this data using the most advanced communication techniques.

On-line monitoring systems have already been developed, however this was mainly for HV circuit breakers. The challenge in MV is to achieve a result with a cost that is compatible with the cost of the circuit breaker.

MAINTENANCE STRATEGIES

Maintenance for electrical equipment can be classified into 4 categories:

- Corrective maintenance
- Systematic preventive maintenance
- Conditional preventive maintenance
- Maintenance based on the RCM method (Reliability Centered Maintenance).

Corrective Maintenance involves returning the device to full working order following an observed defect.

Systematic preventive maintenance involves servicing or replacing wear parts, carried out at regular intervals of time or of service life.

Conditional preventive maintenance involves carrying out maintenance operations on the basis of a forecast of potential failure. Diagnostic resources are necessary to establish these forecasts.

Reliability-Centered Maintenance (RCM), in addition to the condition of the equipment or the system, takes account of the equipment’s importance in the network. This importance will be assessed based on the impact of failure in financial, commercial and even social terms.

It is notably based on FMEA failure mode and effect analysis type methods.

Conditional maintenance allows us to service equipment at the appropriate moment before failure. RCM also allows us to define an optimum maintenance policy for all of our equipment base. It is this type of maintenance that will allow us to achieve the objectives of reduced costs and improved reliability.

The case of a medium voltage circuit breaker

Circuit breaker maintenance requirements have considerably changed with changes in breaking techniques.

Oil or air breaking circuit breakers required regular maintenance operations notably due to contact wear. Unfortunately these operations did not stop failures.

With SF6 or vacuum breaking technologies, current circuit breakers achieve a good level of reliability and allow manufacturers to call them: "maintenance-free". In taking this sales term to the letter, customers may think that circuit breakers no longer need looking after.

Perhaps it would be more precise to say: "systematic preventive maintenance-free", as long as the device is operated under the so-called "normal" conditions for which it has been designed.

Circuit breakers play a key role in the electrical network, any malfunctioning can have repercussions out of all proportion with their own value: endangering the safety of people or property, loss of production or power outage.

Up to now, during preventive maintenance operations, two types of operations were in fact carried out at the same time:
- maintenance actions in their own right;
- inspection of control points allowing the condition of the device to be checked.

With so-called "maintenance-free" ranges, the risk is that regular inspections are no longer carried out, especially since a circuit breaker only shows its presence relatively infrequently in the instance of a defect.

Moreover, since it has a life cycle of around 20 to 30 years, and since nothing allows us to check, when in service, whether it is still capable of carrying out its role of protection, it appears necessary to replace the idea of inspection (physical) by a permanent maintenance function.

This is what we propose to achieve with the "Monitoring module" fitted on-board the circuit breaker.

THE MONITORING MODULE

Operating principle

The general principle of the monitoring module is to collect data in order to be able to formulate a diagnosis of the device's condition.
Checking that the circuit breaker is in good working order is achieved in 2 manners:

− **Checking operating conditions:** correct operation of the device depends on external conditions such as auxiliaries voltage, or environmental characteristics. His involves making sure that operating conditions indeed correspond to those for which the circuit breaker has been designed.

− **Monitoring behavior over time:** in terms of internal aspects of the circuit breaker, we have to collect significant parameters relative to its behavior over time. Analysis will allow us to diagnose the circuit breaker's working condition.

It is relatively easy to position operating conditions (external) relative to limits of acceptability defined by device designers.

As opposed to this, the characteristic operating values, such as circuit breaker opening and closing times, depend on a large number of parameters: auxiliaries voltage, temperatures, number of switching operations, etc.

Considering the large number of factors that influence the measured characteristics, modeling techniques not yet sufficiently reliable to allow us to automatically diagnose the circuit breaker's condition. At present, it is still necessary to involve a circuit breaker expert in order to interpret the results of measurements and draw conclusions on the device’s behavior.

Furthermore, besides the intrinsic value of the measured parameters, the expert will analyze how they change over time, and the more the past data is analyzed, the more accurate the diagnosis will be.

It is therefore particularly interesting for the monitoring module to be operational as soon as the circuit breaker is put into service.

In order for the monitoring module to become the circuit breaker's "memory" and remain associated with it throughout its life, it will be useful to fit it "on board" the device.

In order to be acceptable, the extra cost generated by integrating the module must not exceed 5 to 10% of the circuit breaker cost.

In order to achieve this, we have to limit the number of monitored parameters to what is "strictly necessary", in other words those that allow us to detect potential mechanical failures (which represent 80% of circuit breaker failures).

**Monitoring module functions**

**Basic function:**

The monitoring module measures operating condition values such as:
- auxiliaries voltage
- ambient temperature
- number of switching operations

and gives a warning concerning any values outside of a set range of acceptable values.

This function is provided to the user, entirely independently of operation.

**Advanced function:**

As seen previously, diagnosis should be based on monitoring measured values, but above all focused on how they change over time.

The monitoring module will therefore play a role as a "black box", by recording:
- The device’s operating conditions: the minimum and maximum values chosen are recorded every 24 hours;
- For each switching operation, the value of mechanical device operation characteristics relative such as opening time, closing time or control mechanism loading time. Furthermore, we will record the date and precise operating conditions during these events.

This recorded data will be taken at regular intervals (frequency to be defined according to operating conditions) and sent to a technical competency center having a knowledge base on the whole circuit breaker range.

An expert will therefore be able to analyze the data and formulate an operating diagnosis for the device.

As appropriate, he will recommend an in-depth on-site investigation that will allow him to carry out a more detailed diagnosis.

**Additional functions: the maintenance note pad**

The use of electronics now allows us to provide new functions.

In this module, we have chosen the "Note pad" function, which allows the operator to record the actions carried out on the device.

**Installation**

The module can be installed at any time; ideally, the circuit breaker should be equipped with it from initial commissioning.

When commissioning, the module will have initial parameters input to record:
- circuit breaker characteristics
- factory values, when they are known
- alarm trigger limits
Usage

Whatever the function of the module, all of the data is available:
- locally (on the circuit breaker or in the low voltage compartment)
- throughout the monitoring system connected to a local MODBUS RS485 network, notably the Transparent Ready™ system (described below), using WEB technologies.

The user can therefore:
- consult displays on the front face of the module;
- operate the fault relays;
- input the various operating and monitoring parameters using UMI software provided with the module and installed on a laptop PC;
- using this same software, locally extract and display the recorded data;
- use the recorded data, or have it analyzed remotely via the monitoring system.

Application to an installed equipment base

Whilst these monitoring functions appear necessary to monitor the performance of new devices, the interest is naturally just as significant for equipment already installed:
- The older the devices, the higher the risk of failure,
- The past history of actions carried out on the equipment is not always accessible and consequently the condition of the equipment remains an “intuitive” assessment.

This leads to the idea of a similar module that can be adapted to all MV circuit breakers, offering some of the previous functions. This allows us to monitor all of the equipment in the installation and therefore build up a database which will be used to define an optimum maintenance plan.

Our expertise becomes greater as more and more data is collected (the more data there is, the more accurate the diagnosis). The more circuit breakers are “covered” in this manner, the more relevant the Maintenance Plan will be.

In this respect, monitoring modules should be connected to an information system that transparently collects and interprets the data.

INTEGRATION IN TRANSPARENT READY™

Transparent Ready™ is the name of the concept presented by Schneider Electric which is intended to offer complete Transparency of data in an automated system via Web technologies.

More specifically, this concept is based on a "seamless" architecture with the Modbus mail system as the backbone (Modbus on a series line, Modbus on Ethernet), which is combined with Web protocols (HTTP, FTP, POP, SMTP, SNMP) and technologies (HTML, XML, mail, SMS...).

This combination proves particularly relevant in electrical network monitoring systems by providing the operator:
- With a new approach to monitoring the network at a cost that is a real breakthrough compared with conventional installations
- True communication transparency
- Total adaptability to requirements by allowing the optimal system to be chosen (series line or Ethernet)
- True transparency of data: all that an operator needs now is a PC equipped with a browser, such as Internet Explorer, to access the data
- Total freedom in the way that the data is used. These IP-based technologies take no account of distances, and can naturally use the internet for transmission. Consequently, data access can either local, remote on-site, or remote off-site.
- Guaranteed inter-operability and scalability, all of the technologies used being truly world-wide and open standards.
- The ability to use an existing communication infrastructure (e.g. Ethernet)

Associated with Transparent Ready™, it is also important to consider the idea of the class of service expected by the final operator (or final operators). By class of service we mean all of these services that the operator expects the system to provide:
- Monitoring
- Monitoring and alarm
- Monitoring, alarm and trends,
- Monitoring, alarm, trends and control
- And/or non real-time monitoring by a service provider

Through its possible technical interfaces, the monitoring module is perfectly integrated in a Transparent Ready™ architecture and therefore potentially benefits from all of these services.

It can constitute the basis of a system focussed on installation diagnostics, or it can be complementary to a system which otherwise provides the functions of protection, metering or control:
Case of a Transparent Ready™ system exclusively oriented on diagnostic functions and therefore based on the monitoring module (SD4) in a class of service allowing direct access to the data:

Web pages are provided by a Web server fitted to the equipment. Once loaded in the operator's browser, the data is automatically updated. This operating procedure can be implemented locally or remotely via Intranet or Internet.

Case of a Transparent Ready™ system combining monitoring and diagnostic services

Architecture similar to the previous one but acting on a broader operating perimeter, notably including the protection and metering functions of multi-function protection relays such as Sepam.

Case of a Transparent Ready™ system using a remote services provider (e.g. maintenance):

In this case the data is collected by the server, which regularly takes the initiative of pushing this data towards the service providers' databases. Based on the systematic collection of data, the service provider can formulate data overviews intended for operators. This sort of server can be globalized at full installation level.

However, such a system can also be integrated in a conventional monitoring system for electrical networks, and therefore use a centralized device to provide this function:

It should be noted that the price of acquiring this conventional system can be up to ten times greater than the price of an installation that is truly based on new technologies (such as the Transparent Ready™ system).

It therefore now appears clear, that new Web technologies are the basis of a breakthrough relative to the issues we face in this respect. The appropriate use of these new technologies can provide new services to the end user, notably providing access to data under conditions that were impossible to imagine even just a few years ago.
These new conditions for data access are what greatly increase the interest of a circuit breaker monitoring module.

ECONOMIC ASPECTS

Let's now examine the economic impact of the choices we have so far seen and described:

Limiting the number of parameters to be monitored has the aim of being focused on the main issue in order to minimize the cost of the circuit breaker. Integrating enhanced on-line functions will certainly allow more detailed analysis of the circuit breaker's condition, but will not eliminate the need for human involvement in order to interpret the results.

The use of an expert to formulate a diagnosis would seem to be an optimal solution in technico-economic terms:
- It is not very frequent
- Thanks to NITC, it can be carried out remotely, with standard resources, and therefore relatively inexpensively
- Due both to the memory of circuit breakers, and to the experience base acquired from a large equipment base, the expert will have the ability to provide an accurate diagnosis.

As for the cost effectiveness of the system, the calculation significantly depends on the installation in which it is integrated. Among the points to take into consideration we can note:
- The number of circuit breakers to be monitored
- The type of communication equipment
- The monitoring and maintenance policy
- The impact of a failure
The last parameter is doubtless one of the most decisive, but if often remains the most difficult to assess.
In this respect, the investment is comparable to insurance.

CONCLUSION

In the system that we have presented above, we have tried to achieve a technico-economic compromise making monitoring and low cost compatible. Integrating of new functions to move towards a "self-diagnosing" system will depend:
- On technical progress that will allow us to reduce costs
- On the interest taken by customers, interest which will be a strong driver for manufacturers in pursuing their investigations.
However, technical performance levels are not an end in themselves: beyond the monitoring functions themselves, it is all of the services expected by the customer that have to be developed.
The monitoring module has been designed with this in mind, by including in particular the possibility of integration in an architecture such as Transparent Ready™.

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