The watchdog: a main component in the protection scheme

Abstract

The watchdog is one of the most important parts of the Sepam monitoring system for it notifies the operator whether the protection functions of the Sepam are in working order. This monitoring system is based on self-tests. If an internal failure is detected, the Sepam is put in standby position. The watchdog should also be used as a back-up protection in order to maintain primary safety when the Sepam is in standby position. This shows that the protection relay is useless without a global protection scheme which takes into account the possibility of a failure of the Sepam. A compromise has to be found between safety and availability of the electric network regarding the needs of the plant. As the behavior of the Sepam in standby position is linked with the type of the watchdog, the choice of this component is crucial.

Index terms – watchdog, monitoring system, standby position, back-up protection, protection scheme, safety and availability, undervoltage coil, shunt trip coil.

Introduction

The aim of the Sepam relay is to manage electric installation by providing safety and availability of the installation and the equipment. The protection scheme can be improved with the use of the watchdog. This simple component is really an important part of the protection plan and can easily provide higher protection.

Definition of a watchdog

The watchdog contact is a change over contact: the contacts normally closed of the relays are connected in daisy-chain

Figure 1 – Watchdog contact
The watchdog should be used...

..As a notifying device of the monitoring system

The Sepam relay is equipped with a self monitoring system which is able to detect most internal failures in protection circuits of the Sepam. This monitoring system is based on self-tests. The purposes of the self-tests is to detect internal failures that may cause unexpected tripping or non-tripping. If such a failure is detected by the self-tests, the Sepam is put in standby position. In this position, all protections functions are turned off in order to avoid any unwanted operation, logic outputs of the Sepam are open and the watchdog is activated. Please note that some internal failures has no consequence on protection functions of the Sepam.

<table>
<thead>
<tr>
<th>State of the Relay</th>
<th>Watchdog</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>In standby position</td>
<td>activated</td>
<td>Internal failure detected OR Relay not energized</td>
</tr>
<tr>
<td>In working order</td>
<td>not activated</td>
<td>Relay energized AND no internal failure</td>
</tr>
</tbody>
</table>

Fig. 2 – the standby position

The watchdog is an important part of this monitoring system because it indicates if the protections functions of the Sepam are in working order. If an internal fault is detected by the Sepam, a light of the Sepam front panel automatically flickers even if the watchdog is not connected to the system. The fact is that in case of an internal fault of the digital relay, if the watchdog is not properly connected to the control system, the only way to notice that the relay has failed is to control the front panel of the relay. The watchdog contact should therefore be connected to the higher level system in order to generate an efficient alarm and give the state of the relay. For example, a hooter in a plant or a bigger flickering light can be activated in order to inform the operator.

<table>
<thead>
<tr>
<th>State of the Watchdog contact</th>
<th>No failure detected</th>
<th>Internal failure detected</th>
</tr>
</thead>
</table>
| Watchdog properly connected to the control system | Protections functions are in working order | - Protection functions are out of order  
- Sepam in standby position  
- The alarm light of the Sepam front panel flickers  
- **Watchdog contact activates an alarm system operator is notified that a maintenance operation is required thanks to the connection to the control system** |
| Watchdog not connected | Protection functions are in working order | - Protection functions are out of order  
- Sepam in standby position  
- The alarm light of the Sepam front panel flickers  
- **The need of maintenance is detected only if an operator controls the front panel of the digital relay** |

Fig. 3 – the watchdog, a warning system

1 In this case, the Sepam is said to be in downgraded working order: some internal failure has been detected but no protection function of the Sepam has been affected
The first step of maintenance operations is to be kept informed of the state of the device. Thanks to the watchdog, the maintenance staff is warned of the state of the protection relay and could repair the faulty device without delay. The use of the watchdog is the main solution because this is often enough to prevent damage to equipment and to avoid loss of production.

Although the self monitoring system of the Sepam will find most internal failures, some may not be detected. Those are mainly linked with the different modules of the Sepam such as disconnected sensitive earth fault current transformers, failure of input / output modules or also faulty analog output module. Those failures do not concern the relay itself but may have important impacts on the protection functions. For example, if a core balance current transformer used in order to measure the sense of the current is linked with the Sepam in the wrong way, it will have impact on all directional protections. For this reason we recommend periodic testing even when self monitoring is provided.

Considering the frequency of those faults, 5 years between each maintenance operation should prevent the plant from such problems.

<table>
<thead>
<tr>
<th>Functions</th>
<th>Type of self-test</th>
<th>Execution period</th>
<th>Fail-safe position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply</td>
<td>Detection of processor power supply outside tolerance range</td>
<td>At time of energizing and continually</td>
<td>YES</td>
</tr>
<tr>
<td>Acquisition of currents or voltages</td>
<td>Detection of analog channel saturation</td>
<td>Continually</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Filtering by data signal processing</td>
<td>Continually</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Test of presence and recognition of connector</td>
<td>At time of energizing and continually</td>
<td>YES</td>
</tr>
<tr>
<td>Processing unit</td>
<td>Memory test</td>
<td>At time of energizing and continually</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Software watchdog</td>
<td>Continually</td>
<td>YES</td>
</tr>
<tr>
<td>UMI</td>
<td>Memory test</td>
<td>At time of energizing</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Software watchdog</td>
<td>Continually</td>
<td>NO</td>
</tr>
<tr>
<td>Logical I/O</td>
<td>Test of presence and recognition of module</td>
<td>At time of energizing and continually</td>
<td>YES (1)</td>
</tr>
<tr>
<td>RTD inputs</td>
<td>Memory test</td>
<td>At time of energizing</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Software watchdog</td>
<td>Continually</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Analog conversion test</td>
<td>Continually</td>
<td>NO</td>
</tr>
<tr>
<td>Analog output</td>
<td>Memory test</td>
<td>At time of energizing</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Software watchdog</td>
<td>Continually</td>
<td>NO</td>
</tr>
</tbody>
</table>

(1) only when the module is missing or if there are not enough logical inputs

Fig. 4 – The self-tests of the Sepam
..As a back-up protection

The watchdog contacts can also be used to provide back-up protection by other relays. The back-up protection is a brilliant solution in order not to depend only on one Sepam that might be faulty but also on other Sepam that protect the upstream electric network.

If the protection system is built according to the state of the art, each fault should be detected by at least two different protection relays. This can be achieved either by installing 2 different protection relays on one circuit-breaker (commonly used on transmission systems) or by relying on the upstream breaker and its protection relay (very common in distribution systems). This basic principle can be improved by using the following back-up protection system

The back-up protection system is really simple and uses the fact that a protection scheme is composed of upstream protection relays and downstream protection relays. If the downstream Sepam relay is in standby position, the protection functions are not in working order. An electric network failure may happen and damage the power system that should have been protected by the Sepam. The answer to this problem is to wire the watchdog contact of the downstream Sepam relay with the protection of the upstream Sepam relay.

An example is described below (Fig. 4.)

![Fig. 5 - Example of the use of watchdog contact in a back-up protection](image)

The relay F2 is in working order whereas the relay F1 is in standby position as the watchdog is closed. Therefore relay F1 does not provide any protection anymore. If a short-circuit occurs in the network which was protected by F1, the back-up protection F4 will trip the circuit-breaker controlled by F1 thanks to the back-up trip circuit.

Furthermore, any back-up scheme which uses the watchdog contacts of microprocessor relays must still provide the minimum back-up protection in the case of undetected failures in the relay or circuit-breaker failure. The protection of a power system using Sepam protection relays is secured, but the
power system has to be protected even if the protection function fails. Using the watchdog as a back-up protection increase the availability and the safety.

**Protection scheme**

Since many protection functions are included in one device, a reliable protection scheme is very important in order to protect capital equipment, to protect operating personnel, and to reduce down time by selectively clearing faults.

Correct operation of the protection circuit including back-up protection may ensure optimal clearance of the fault but will not in itself prevent a loss of production. In other words good back-up protection will not fix a bad design.

The reason for extensive damage in installations is not often a faulty protection equipment itself but how the protection scheme has been designed and implemented.

The protection plan should be designed in order to obtain the best combination of protection and continuous operation. Any analysis of back-up protection must take into account the complete protection circuit that consist of the circuit-breaker, the instrument transformers, the auxiliary power supply, and the relay. Even the most advanced protection relay is useless without a well-designed protection scheme: if the protection equipment is incorrectly wired and the relays incorrectly set, the availability and the safety of the power system can not be ensured.

**Safety and availability**

A protection system has to ensure two main functions:

- To protect the electric installation/components against overloads, and short circuits due to component failures and therefore to avoid accidents (fires, explosion) that may follow. This function is linked with safety.
- To provide power so that electrical equipment can run properly. This function is linked with availability.

As explained before, a good protection scheme takes into account the possibility of a failure of the protection relay. Furthermore, it is established that some failures caused more damage to safety than to availability and vice versa:

- A failure to trip of the protection relay may lead to the destruction of components. This can start fires which may turn into explosion. This is, of course, always associated with human risks.
- False trip of a protection relay may trouble the production availability of the installation. This may lead to a partial or a complete loss (blackout) of the production. This often implies an important financial loss.
Safety and availability are conflicting requirements: improving the one decreases the other one and reciprocally. Therefore designing a protection scheme has to be a good compromise between safety and availability.

**The appropriate watchdog**

Failures have different impact on the electric network depending on their type, their location, the need of the plant. It is possible to distinguish two main types: the “safe failures” and “unsafe failures”. It is really important to note that those two types depend on the need of the plant. It is no sense to talk about a “safe failure” in a universal point of view.

The protection relay has to ensure availability when “safe failures” occurs and must prevent the power system from “unsafe states”. As a consequence, the standby position is a main issue and has to be carefully tackled.

The so-called “safety state” actually depends on the kind of MV application. In most applications the de-energizing of the system will be the safe state. For instance it is often requested to stop a motor in case of over-current. But in some specific cases, it will be safer to keep the system energized. For instance, some safety pumps need to be kept running even in case of MV failure.

This is a problem for manufacturers to address properly requirements of safety and availability. This issue can be solved by using a temporary "standby" position. In this state, the protection relay is stopped, and alerts the system for curative maintenance within limited time (24 hours) as showed below (Fig. 4).
In applications where safety is crucial, the system designer will choose a safety-oriented architecture. In case of a failure detected by self-testing, the system will go into the Safety state, resulting in circuit tripping. If the safe state of a system is to de-energize it, the use of "under-voltage" coils mode will ensure safety. In applications where safety and availability have to be balanced, using "shunt trip coils" may ensure a compromise between safety and availability. When self-testing detects a protection relay failure, or when the power supply is faulty, the watchdog relay is activated, and an upstream protection relay replaces the downstream faulty protection relay during the fault condition period. Using "shunt trip" coils when the safe state of a system is to de-energize it will ensure a compromise between safety and availability.
PROTECTION IS RUNNING

Watchdog linked with the protection relay

No watchdog linked with the protection relay

FAILURE OF PROTECTION RELAY

STANDBY POSITION
- a failure was detected by self-tests
- WD activated
- protection function are turned off

HAZARDOUS STATE
- protection functions seem to be working
- protection functions are actually inoperant

ELECTRIC NETWORK FAILURE

SAFE STATE 1
- Circuit breaker is open
- MV energy is not more available

SAFE STATE 2
- Circuit breaker is open
- MV energy is not more available
- Watchdog is activated

Watchdog fulfilled with undervoltage coil

Watchdog fulfilled with shunt trip coil

Watchdog contact used for back-up protection

BACK-UP PROTECTION
- External back-up protection device activated by watchdog contact
- Without maintenance within 24h, protection system must be set in safe state

SAFE STATE 1
- Circuit breaker is open
- MV energy is not more available

ACCIDENT
**Conclusion**

The Sepam relay provides safety and availability of the electric network thanks to its monitoring system. But the use of the watchdog -carefully chosen before- and the back-up protection increase the safety and the availability. The protection of an installation or equipment should be considered as a global system –the protection scheme- and not reduced to the protection relay itself.