Case study

Leonardo ENERGY

Power Quality

Didier Empain
Laborelec

December 2007

Troubleshooting the logic selectivity system of network protections

European COPPER Institute

Power Quality

Introduction

A large plant in the transport sector was experiencing a general voltage interruption caused by a local short-circuit inside the plant's electricity network. This happened because of a non-selective tripping of the general protections at the plant's connection point. The company decided to take action to identify the origin of the malfunction and implement corrective measures. An electricity consultant was called in to investigate the case.

1. Problem description

1.1 Theoretical background

When a fault occurs, only the protection device (or devices) closest to the fault should react to isolate the faulty network section. This is called good selectivity. If not, other parts of the network will unnecessarily be without power, causing production losses as well as potential equipment damage and security problems. Such a selectivity problem ('unselectivity') is caused by an erroneous setting or a malfunction within the protection system.

The protection system is composed of:

- A circuit breaker that physically isolates the faulty section

Figure 1 : Circuit breaker

- Measurement transformers providing voltage or current values to the protection relay

Figure 2 : Measurement transformers

- A protection relay interpreting the measured values and giving trip orders to the circuit breaker

Figure 3 : Protection relays

A variety of circumstances can cause unselectivity, including faulty operation of the circuit breaker (failure to open), erroneous settings, relay failure, and loss of measurement values.

The techniques to ensure selectivity depend on the type and technology of the relays. It also depends on the structure of the network: meshed and radial networks cannot be protected by the same technology since in a meshed network the power can flow to the fault from both sides.

If the network is radial (as in most cases), it is possible to use overcurrent protection relays, which only measure the RMS value of the current. Ensuring selectivity with this kind of relay can be accomplished by varying the time delays of the relays. This is called chronologic selectivity.

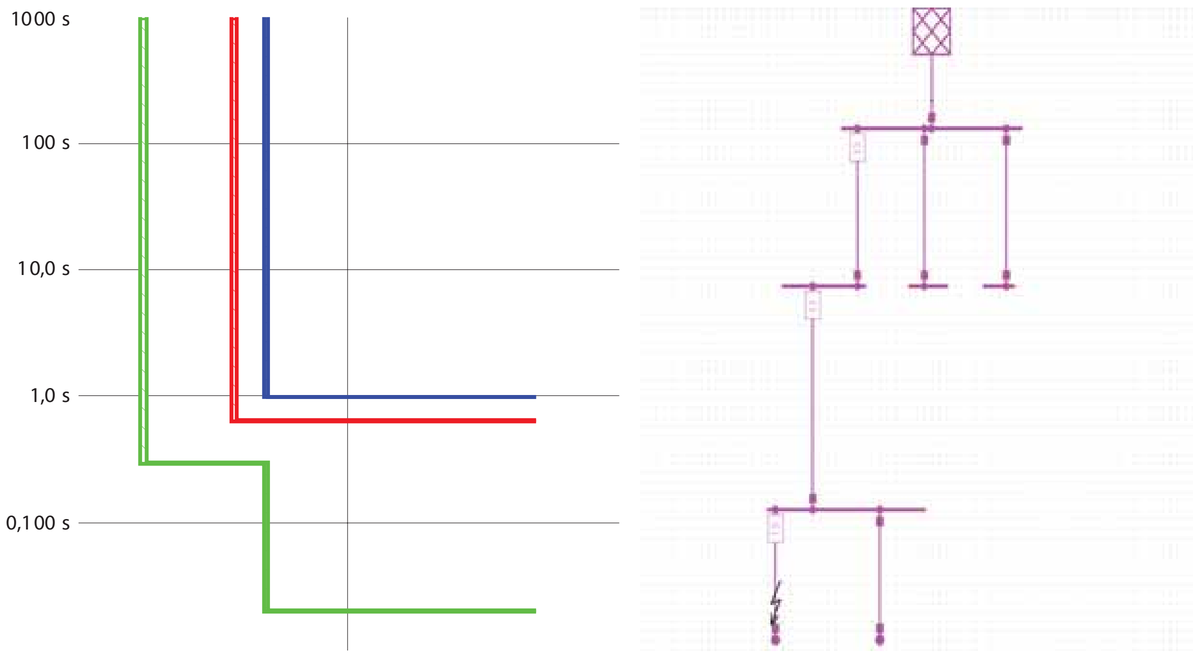

Figure 4 : Chronologic selectivity

This concept is shown in the above diagrams. The right diagram shows the network with the three levels of relays. The left diagram shows the tripping points of the relays on the time/current plane. The blue line represents the relay closest to the injection point, the red line represents the middle relay, and the green line represents the relay downstream in the network. The fault indicated in the right scheme should be eliminated by the relay immediately upwards (green curve). Indeed, the green relay reacts faster than the others. The fault current flows through the entire network for a short time, but once the nearest relay has reacted, the fault current disappears in the rest of the network and no other relay will trip.

The major disadvantage of this system is that there can be a relatively long time delay before the fault is eliminated. This delay can lead to equipment being damaged.

In a meshed network, other selectivity techniques are used, including impedance protection or differential protection. These systems are capable of detecting the location of the fault and the direction of the fault current. They are not discussed in further detail in this paper.

Another concept is to use overcurrent relays with a logic selectivity system. This concept was the one being used in this plant's network.

1.2 The network of the plant

In principle, the plant's network is radial, but its concept is very flexible, thus enabling various configurations. At some locations, the power can come from several different parts of the network. There are also some closed loops. So in reality, this is a partly meshed network. The protection system consists of overcurrent relays with a logic selectivity system.

A logic selectivity system functions as follows: when a relay is activated by a faulty current (i.e. a current higher than the threshold), it first sends a blocking order to the relay immediately up the grid. The only relay that isn't receiving any blocking order is the one that is nearest to the fault. Consequently this relay will trip. This system allows the setting of all relays at an equal base time delay.

Due to the closed loops in the plant's network, the feeding power can come from two directions. The relay therefore has to adapt the direction of the blocking order, which is accomplished by performing a directional measurement. This measurement is based on the difference in phase angles between current and voltage, taking into account that the network is strongly inductive in the event of a fault.

The overcurrent relays can be used to protect the system against a phase overcurrent or against a zero-sequence overcurrent.

- When protection against a phase overcurrent is in place, it is possible to define several threshold values with a corresponding tripping delay. For example, one threshold just above the normal load current with a delay of 1 second, and another much higher threshold without any delay to react in the event of a severe short-circuit
- For protection against a zero-sequence overcurrent, the directional measurement is executed by an external directional relay. When a zero-sequence overcurrent occurs, this external relay will forward the required direction of the blocking command to the main protection relay

1.3 Identifying the problem

As already noted in the introduction, a local short-circuit further down the plant's electricity network was causing a non-selective tripping of the general protections at the plant's connection point.

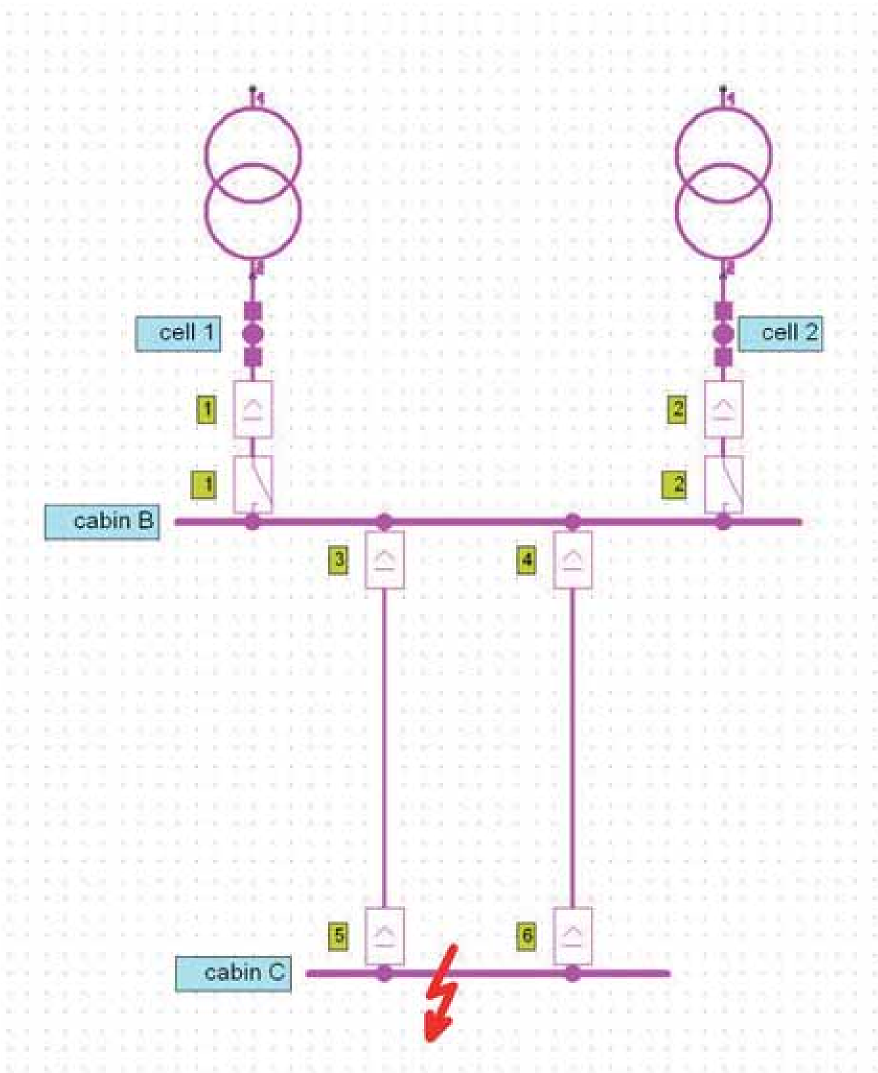

Figure 5 : Fault location in the grid

Relays 5 and 6 should have reacted to eliminate the fault, but they did not. Instead, the main protections 1 and 2 tripped. This is called unselective tripping.

Three hypotheses can explain this behaviour.

1.3.1 First hypothesis

The relays of cabin C have not tripped as they should, but they do have transmitted their blocking orders to the protection systems in cabin B. The main protections (relays 1 and 2) have then tripped, since they have a second, back-up threshold that cannot be blocked by relay 3 and 4 and provokes tripping after 1.5 seconds.

But relays 3 and 4 also have a second threshold that cannot be blocked, and which provokes tripping after a delay of 1.1 seconds. Relays 3 and 4 should therefore have reacted already before relays 1 and 2. For this reason, this hypothesis was quickly abandoned.

1.3.2 Second hypothesis

No blocking orders have been transmitted from cell 3 and 4 to the main protections (1 and 2). The main protections tripped after 0.6 seconds, and did so faster than the relays of cabin C, which are also delayed 0.6 seconds.

1.3.3 Third hypothesis

The third hypothesis is similar to the second. The blocking orders transmitted from cell 3 and 4 to the main protections (1 and 2) did not function properly. This third hypothesis assumes that these blocking orders got stuck inside cabin B by erroneous communication in the bus system. The origin of such an error could be in the configuration of the busbars. This hypothesis will be developed later in this document.

2. Solving the problem

The records of the incident did not enable a complete understanding of what went wrong. The consultant therefore decided to carry out an exhaustive testing of the installation.

In this type of protection system, the communication between the relays is the principal weak point. The consultant therefore started by testing the performance of all communication signals between the relays. He activated the blocking command and verified whether or not there was good reception of the signal on the wiring of the corresponding relay. All signal transmissions functioned properly; both those between Cabin C and Cabin B as well as those between relays 3 and 4 and the main protections. This eliminated the second hypothesis from further consideration.

However, the communication signals between relays 5, 6 and relays 3, 4 were reversed. What will be the consequence? Suppose, for instance, that the busbar of cabin B connecting to cell 1 is open. In that case, a fault downstream between relay 5 and relay 3 will block relay 2, which is not concerned by the fault. Relay 1 will not be blocked and will consequently react after the base time delay. In short: the relays will not react in a proper selective way.

To explain and solve the problem, the consultant carried out more tests. He verified how the relays react in practice when they are measuring an excessive current.

The consultant decreased the blocking threshold of relays 3 and 4 below the value of the nominal load current. A nominal current would consequently be regarded as a permanent fault and the relays would send a blocking order upstream. He subsequently injected a fault current in relays 5 and 6 with a value higher than the nominal current, but lower than the second threshold that rules out all blocking actions and makes the relays trip immediately. When the test was carried out, the coupling of the main busbar opened. The blocking orders from relays 3 and 4 to relays 1 and 2 were interrupted, and the latter tripped after the base time delay.

This result was not surprising. The busbars have several couplings creating various configurations. The transmission of the blocking orders depends on these configurations. If transmission of the orders gets stuck, the relays may not react properly. This was clearly demonstrated by the test.

3. Corrective actions

An exhaustive investigation of the transmission wires in post B was executed.

One of the suggestions by the consultant was to create a longer time delay for the transformer's protection relays to make them independent of the logic selectivity. Then if the logic selectivity does not function properly due to a bad transmission of the orders, this increased delay will prevent the general relays from tripping.

4. Other options

A logic selectivity system depends entirely on the communication orders between the related levels. The primary risk in using this system is that a communication malfunction can affect selectivity, provoking unwanted tripping. An alternative is to use a classical overcurrent protection system with chronologic selectivity, as discussed in 1.2.

Both chronologic selectivity and logic selectivity have certain advantages and disadvantages.

- Delay before fault elimination: the logic system is faster — the relays have a base time delay, but not an extra delay related to their level in the network as in chronologic selectivity
- Reliability: the logic system is less reliable, since it depends on the communication wiring, and results in a higher probability of non selective tripping
- Flexibility: the logic system allows for more flexibility in the exploitation scheme, while with chronologic selectivity the network topology must be fixed (although relays have at least two parameter sets which allow for adapting their settings according to the exploitation configuration)
- Manufacturer dependency: with the logic system, the operator is technically bound to the manufacturer (if they want to extend the network or replace some elements, the communication system must be compatible)

5. Final conclusion

The consultant presented two possible solutions to the plant to solve their selectivity problem:

1. Keeping the logic selectivity, but adding an extra time delay to the relays of the feeding transformers
2. Changing the logic selectivity into a chronologic selectivity

Both options have advantages and disadvantages. The final decision of which solution to choose is up to the individuals in charge of the plant.