COMMON MISTAKES FOUND IN TURN-KEY DER INTERCONNECTION PROTECTION SYSTEMS

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ABSTRACT

The proliferation of distributed energy resources (DER) in the distribution grid has brought many challenges to the Distribution System Operators (DSO), as they have to ensure that the growing share of DER can be safely connect to the power grid and still maintain the network's safety, continuity of service and power quality requirements.
An interconnection protection relay, placed between the grid and the DER facility, is an important part of maintaining safety requirements. In Portugal, external service providers working for the DER owner perform the installation and configuration of the interconnection relay. The DSO validates the interconnection protection hardware and wiring project, submitted by the DER owner, and provides the adequate relay settings. In the end, the DSO is present at the commissioning stage making sure the relay behaves as expected and may seal it to avoid any unauthorized change.
Even though this workflow has proven its benefits, EDP Distribuição (EDPD) has found some recurring mistakes in the installation and configuration of the interconnection relays that are not prejudicial to the network but often lead to many undesirable trips thus reducing the energy produced by the DER and increasing maintenance costs.
In this paper, authors will present and discuss the most common mistakes made by external service providers in Portugal when installing and configuring the interconnection protection relays.

INTRODUCTION

The growth in the distributed energy resources (DER) connected to the distribution grid has brought many challenges to the distribution system operators (DSO) as they have to continuously comply with restrictive quality of service (QoS) standards, grant the safe operation of the grid and to act as a facilitator of the proliferation of DER.

To archive the three key factors stated, QoS, Safety, and market facilitator, EDP Distribuicao, the Portuguese DSO, relies in an optimized set of parameters for the interconnection protection relay. This set of parameters are the result of several studies and have proven to grant the necessary stability and safety to the operation of the electrical grid.

In Portugal, during the process of connecting a generating plant to the grid, the producer is responsible for:

- The electrical and civil construction project;
- Electrical and civil construction site works;
- Implementation of the settings given by the DSO;
- Planning and conducting the commissioning Tests.

During the same process the DSO assume the responsibility for:

- Validating the installation project;
- Providing the adequate settings for the interconnection protection relay;
- Verify that the interconnection protection relay has the correct settings;

The DSO may also seal the interconnection protection to avoid unwanted modifications in the settings.

Even though the process has proven its benefits, EDPD have been identifying some repetitive mistakes that may not cause any consequences to the grid operation but do cause several trips of interconnection protection relay leading to a decrease in the energy produced and some complains by the Producers.

This paper tries to present these common mistakes, their consequences and propose some solutions to avoid them.

WHAT ARE THE COMMON MISTAKES?

EDPD's success in integration DER are also due, as stated before, to its optimized group of interconnection protection settings. This group of setting include the usage of the following protection functions:

27 – Under Voltage;
59 – Overvoltage;
59N – Neutral Voltage Displacement
81 – Frequency;
50 – Overcurrent Relay;
Directional apparent power function.

During the integration of several turn-key DER installations, EDPD has observed mistakes sometimes being made in the implementation of the interconnection relay settings, which may cause unwanted trips. These mistakes may not be identified during commissioning tests and are only detected after an unwanted behaviour from

the interconnection protection relay.
These mistakes can be divided in 3 different categories: Incorrect implementation of the relay settings, Protection Relay Issues and Wiring Issues.

Incorrect implementation of the relay settings

In this section, the authors will discuss the typical mistakes made in the implementation of the given settings. These mistakes are usually due to the lack of adaptation of the setting to the details of the installation and equipment installed.

Phase to Phase Vs Phase to Earth Voltage Parametrization

It was observed by EDP Distribuição that a common mistake is the confusion between the usage of Phase-to-Phase Voltage or Phase-to-Earth Voltage as the measurement source for the Voltage Protection Relay. This confusion has great impact in the tripping of the Over and Under Voltage functions.

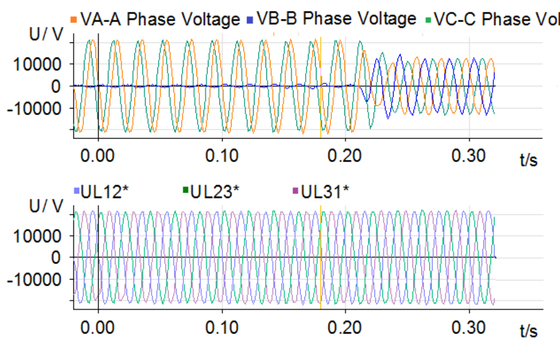

Figure 1 - Comparison between Phase-to-Earth (top wave) and Phase-to-Phase Voltage (bottom wave) during an actual Earth Fault occurred in the Portuguese MV network

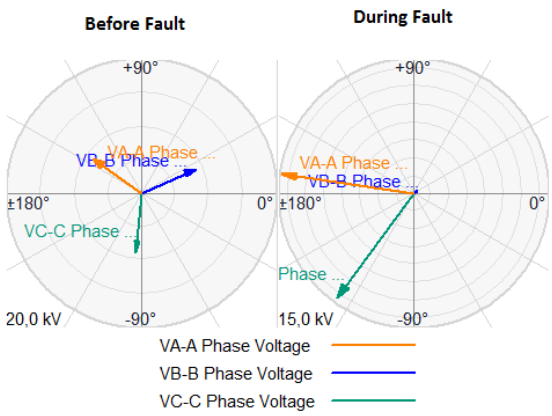

Figure 2 - Vectorial Diagram of Phase-to-Earth Voltages of the fault

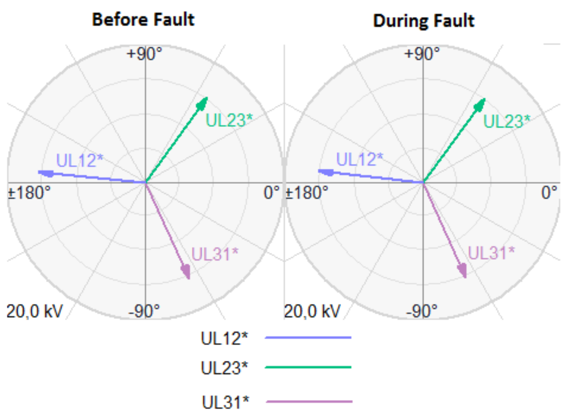

Figure 3 - Vectorial Diagram of Phase-to-Phase Voltages of the fault

In Figure 1, Figure 2, Figure 3 is shown the voltage measured during a real earth fault to illustrate the effects of choosing phase-to-phase over phase-to-ground Voltages. It can be observed that the phase-to-ground voltage of the faulted phase drops to a near zero level, while the healthy phases experience an overvoltage. None of the phase-to-phase voltage presents a significant variation.
If the interconnection protection relay of the DER had the Over and Under Voltages measurement set to Phase to Earth Voltage an unwanted trip by both overvoltage (healthy phases) and undervoltage (faulty phase) would occur in the shown example. If the zero sequence overvoltage is not instantaneous, it will lead to an unwanted trip.
The Over and Under Frequency functions are also affected by the type of voltage measurement because the phase-to-earth voltages tend have wider variations than the phase-to-phase Voltage.

Transformer connection and ratio setting

DER produce its energy at a different voltage level than the grid's voltage level. Therefore, a power transformer is needed to connect the DER to the grid. In order to lower the project costs of the installation, some DER owners opted to have only a point of measurement for the current, typically on the lower voltage side, which will feed the production side protection relays but also the interconnection protection relay
This implies that the measure that feeds the interconnection protection relay, which is obtained in the low voltage side, must take into account the correct power transformer connection (star or delta connection) and its ratio to reflect the actual value of the grid side.

The generation plants, which have this type of design, must have extra care with the settings provided by the DSO. These, which are computed considering the voltage level of the grid, are then sometimes misapplied by not taking into account the transformer ratio. This originates unwanted trips by the Overcurrent protection relay.

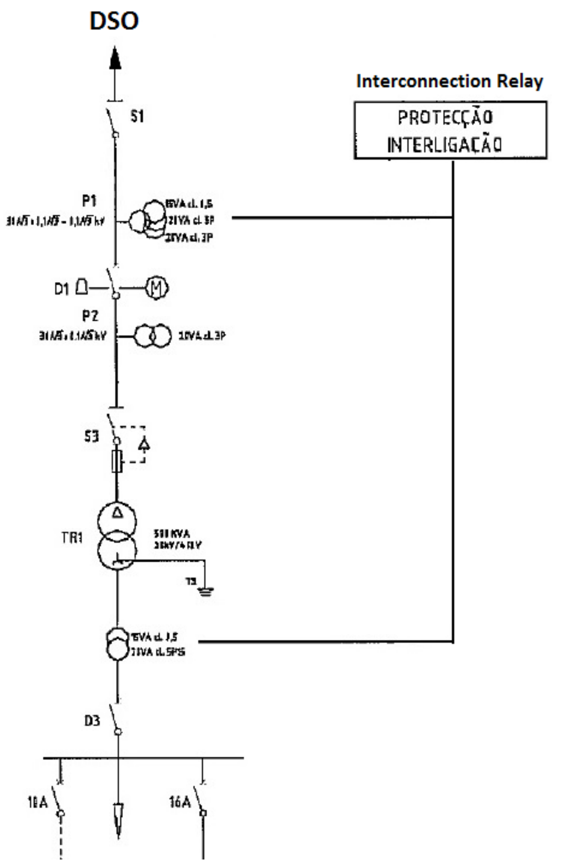

Figure 4 - DER Installation with CT only in Production Side

In Figure 4, a project of a DER Installation with just one Current Transformer (CT) is shown to illustrate the issue discussed in this section.

Protection Relay Issues

This section discusses the differences found in the different relay models, which, if not taken into account when applying the settings, may lead to unnecessary trips.

Frequency protection functions time settings

Each manufacturer employs different algorithms, or different algorithm variants, which may perform differently with different power system characteristics.

The existing algorithms for measuring frequency work under the assumption that the measured signal is stable. During a fault, there is a transition between two stationary, or quasi-stationary, signals. This transition leads a transient on the algorithms output. Some relays filter these output transients, which usually leads to higher starting times.

As it can be seen in Figure 5, during the initial stage of a fault the output of a commercial frequency measurement algorithm varies widely in its amplitude and may reach the set value causing an unwanted trip. As this variation only last for about 30ms it may trip a relay that does not filter it internally is more prone to unwanted trips if it is set to instantaneous.

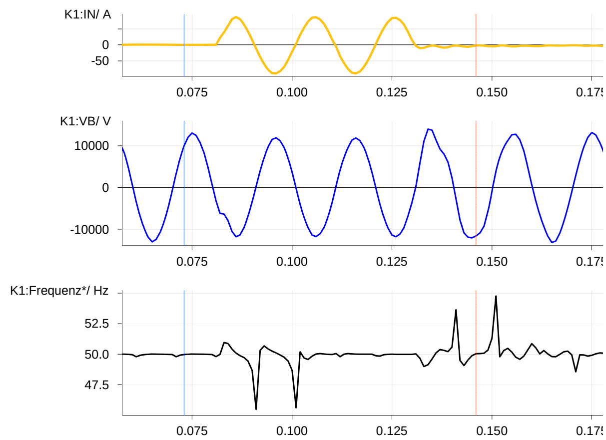

Figure 5 - Frequency behavior during a Fault

As this problem is related to the model of relay used, the responsible for setting of the interconnection relay should apply the necessary delay to the protection to avoid unwanted trips. Usually if the protection unit trips in less than 80ms during a test it will require an additional time setting.
This issue may be difficult to diagnose as it depends on the protection model and most clients are not informed of it.

Zero Sequence Overvoltage Setting (U_0)

Another problem that in often verified is the confusion between the setting of the Zero Sequence Overvoltage (U_o).

Zero sequence voltage measurement is usually obtained through the internal sum of the 3 Phase to Ground Voltages or through an auxiliary transformer with an open delta secondary, like the one shown in Figure 6.

Protection relay manufactures give the user the possibility to choose how the zero sequence voltage is acquired / measured if there is a special input for open delta PTs. Or rely on the value calculated from the sum of the three phase to ground voltages.

Some manufactures design the protection relay interface to allow the setting of the U_0 value while others only allow the setting of $3U_0$. So, sometimes this setting is wrong which will typically lead to an lower than specified operational value which may lead to unwanted trips.

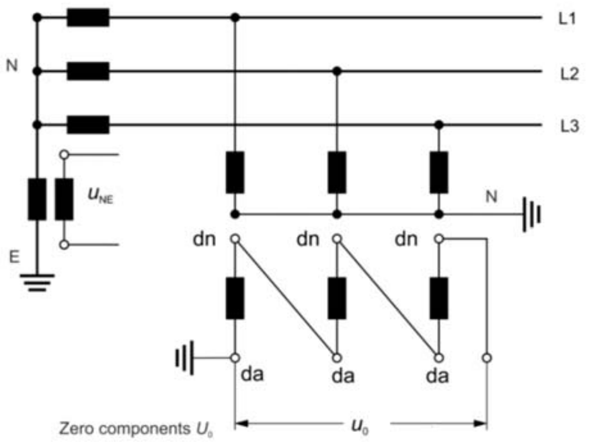

Figure 6 - Zero Sequence Voltage measurement through an Open Delta Connection

The best way to avoid this mistake is to conduct appropriate testing with secondary voltage injection. However, testing itself is not direct and should be done by trained personnel.

Wiring Issues

In this section will be discussed the usual mistakes made during the commissioning stage of the DER installation.

Current and Apparent Power Orientation

To comply with the DER licensing, the Portuguese grid code demands the implementation of a Directional Apparent Power Protection Function that trips when the DER exceeds the allowed licensed power. Most DER has an installed capacity higher than the licensed capacity due to a relatively low capacity usage factor.

The most common mistake in these cases are the incorrect direction of the current transformers that can deceive interconnection protection relay and may not trip when the energy produced exceeds the allowed limit.

This mistake is because the tests for the protection function are done directly in the relay, secondary side, not taking into account the measurement system where the mistake occurs. In addition, the numerous possibilities of direction inversion in the relay contribute to the probability of mistake.

SOLUTIONS TO AVOID THE MISTAKES

Having presented the most common parametrization mistakes found in already full function DER installation in the previous sections, in this section the authors will focus in the discussion of solutions and tips to avoid the mistakes and to minimize unnecessary trips.

Considering the mistakes discussed the easiest solution is to re think the necessary commissioning tests. The purpose of tests required by the DSO is to make sure the generating plant will not cause damage to the rest of the network clients. From this perspective, the tests fulfil their objective. However, they can be enhanced to furthermore minimize unwanted trips.

To avoid the mistake between the Phase-to-Phase Voltage and the Phase-to-Earth Voltage, an additional verification to the ones already being done should be made to confirm the voltage measure origin.

To avoid not taking into account the transformer ratio in the parametrization of the Overcurrent function, the plant with this specificity should be flagged by and the DSO should be aware of this information so new confirmations can be done to ensure the correct behaviour of the system

To deal with various algorithm variants and filtering for frequency measurement DSO should modify the proposed tripping time of the frequency function to include an extra delay time based on the protection function testing results. This extra time is dependent on the protection model.

The installation issues identified in this paper could be solved with enhanced primary tests to the protection relay to take into account possible mistakes made during the electrification of the installation.

CONCLUSIONS

This paper focused in discussing the most common mistakes made in the setting of DER interconnection protection relay. The presented mistakes, which do not compromise the grid’s safety, have been found in already fully function installations and often after several of unwanted trips.

It was identified that the mistakes can be grouped in 3 different categories, incorrect implementation of the relay settings, protection relay issues and wiring issues.

The conclusions proposed are based in two main pillars: the improvement of participation of the DSO in the commissioning tests trying focusing in the identify problems and anticipating new ones; the improvement of the commissioning test by the DER owner especially the inclusion of primary tests to avoid possible errors in directional protection functions.