RENEWABLE INTEGRATION NEEDS AUTOMATION OF CONTINUOUS PROTECTION GRADING

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ABSTRACT

This paper presents an advanced approach for automated and optimized overcurrent grading to face the challenges of an increasing penetration of DGs in distribution systems. The proposed method is also able to define if settings must definitely be changed and if a protection scheme must be improved latest to ensure the protection system security.

INTRODUCTION

Conventional overcurrent grading methods, although they are supported by software tools, are manual, slow, sub-optimal and sometimes they even fail getting a selective and fast tripping solution (e.g. in DG-networks). The integration of renewable energy sources leads to distributed generation with a high number of different operating conditions of the distribution systems. It is necessary to check/reset/optimize the protection settings continuously as well as automatically.

This is very important for distribution system operators also from an economical point of view, only to maintain the settings and to invest in new hardware if really necessary.

The challenge is to define the rules and models for an automated and optimized settings procedure. Hereby the selective coordination must be done regarding practical limitations and the new requirements of the distributed generation.

In order to achieve these goals, the overcurrent protection is studied in two different ways. One way focuses on new characteristics and additional measures. For example, [1] explains how to set the relay with non-standard tripping characteristics to get a faster fault clearing. And [2] describes how to add a communication signal between relays to accelerate overcurrent protection in ring networks. The other way focuses on optimizing the setting procedure with the existing relay characteristics (like IEC or ANSI/IEEE IDMT Standards). [3] shows a effective practical approach. [4]-[6] translate the grading problem into a pure mathematic optimization problem and then using various optimization methods to find the relay setting, which is a popular research topic in recent years.

This paper presents an advanced approach for automated and optimized overcurrent grading to face the challenges. The implemented tool can answer:

- What are the settings with the minimum fault clearing time?
- How near is the setting to the damage limit?
- Is there still enough backup protection for a protected element?
- Should the setting be changed?
- What is the recommended setting if it should be changed?
- Is the installed protection scheme able to ensure the necessary protection security?
- Must the installed protection scheme be upgraded?

CONCEPT OF OVERCURRENT PROTECTION AUTOMATION AND OPMIZATION

General principle of protection grading

Overcurrent protection setting must be matched with:

- Operational boundaries of the protected elements.
- Short circuit current distribution in the network.
- Requirement of main and backup protection.
- Characteristics and setting ranges of relays.

Overcurrent protection grading should ensure with:

- Sensitivity: sufficient main protection for each protected equipment.
- Selectivity: the tripping time of the upstream relay must be long enough to ensure the relay in downstream trip first.
- Speed: the fault should be tripped as soon as possible to minimize the damage.
- Reliability: In case the primary protection fails, its backup should operate immediately to trip fault.

Automation approach

The approach presented here is to set and coordinate the relays one by one automatically to achieve shortest operating time, in the constraints from the protected equipments and sensitivity. The approach considers with the existing relay characteristics (IEC or ANSI/IEEE IDMT Standards).

Basic section

The first difficulty of realizing the automation is the variety of path topology. There can be any possible power system equipment, with any possible numbers, and in any possible sequence in the path. Therefore finding a universal procedure applicable to any possible path topology is the first step. The basic idea adopted here is dividing the path into basic sections. Each section contains one relay and several other equipments, which restrict the setting range of this relay. This idea is coming from the concept of protection zones, but with a practical rule. In detail, a basic section is defined according to the following rules:

- The relay must protect the equipments below it until the next relay.
- If the first equipment below the relay is busbar, then the equipment above this relay is also included in this section, which means this relay should also protect the equipment above it.

The dividing process is illustrated with Figure 1.

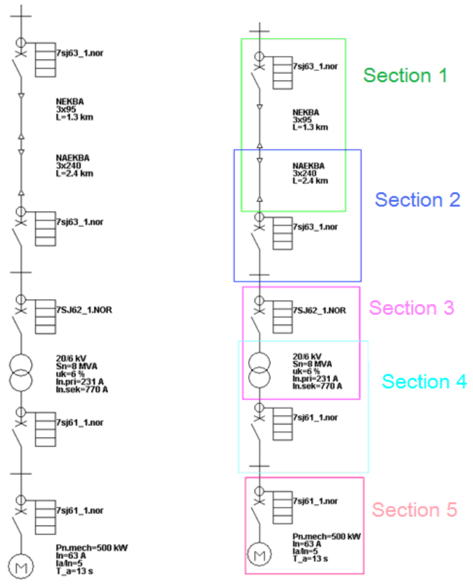

Figure 1: Example of diving path into basic sections

Setting and grading

Based on the basic sections, the setting and grading of overcurrent protection are

- The possible setting area defined by maximum operation condition (as lower boundary) and the damage curve (as higher boundary) of the equipments in one section.
- The relay setting range limits the detail of the setting.
- Each relay is coordinated according to the first relay below it.
- Two adjacent relays are seen as primary/backup relay pair. The one above works as backup protection.

For one arbitrary path, the relays in the path are set one by one towards upstream, as shown in Figure 2. The relay in green section is set first. Then the relay in blue section is set as the main protection in its own section and coordinated as the backup protection with the green section. In the same way, the relay in red section is set and coordinated with the blue section.

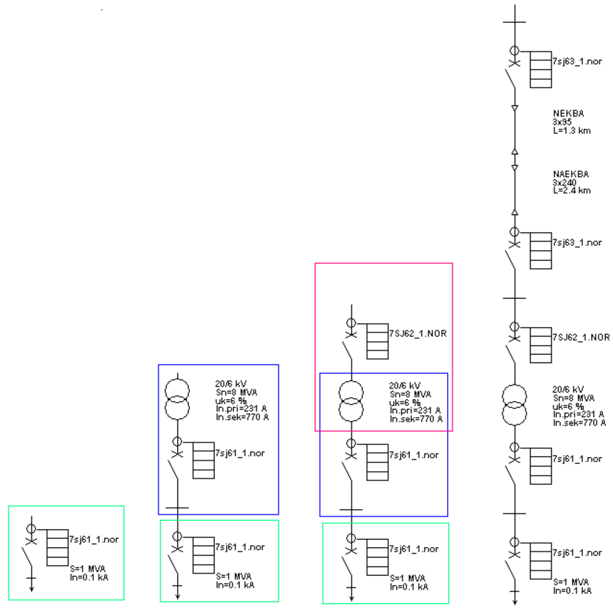

Figure 2: Setting and coordination

The automation of trip characteristic grading is to follow the rules considered the maximum operation condition, SCC distribution and the relation of primary -backup protection. Figure 3 and Figure 4 show, as example, the grading rules with IDMT characteristics, in which the red curve is coordinated with the orange one.

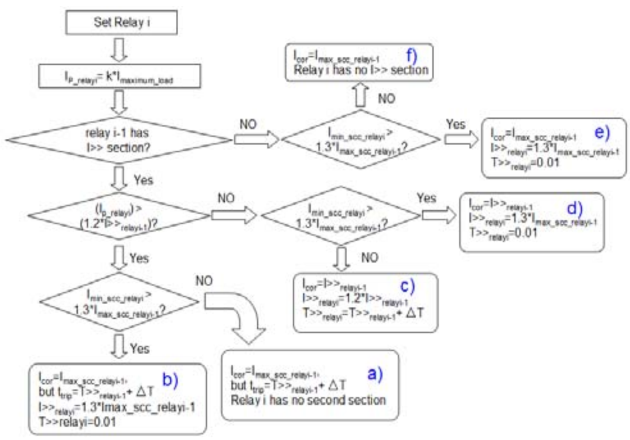

Figure 3: Algorithm of IDMT characteristic grading

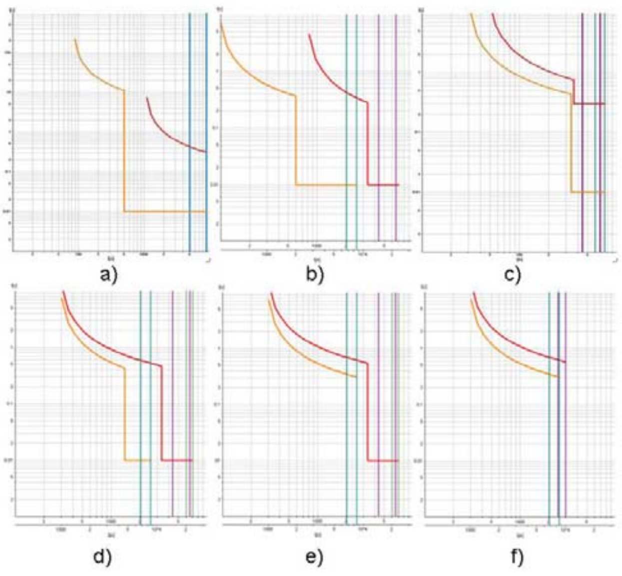

Figure 4: Grading of IDMT characteristic

Optimization in DG-networks

In distributed generation networks, the new grading principle can be applied to reach a more optimal result. This grading principle is coordinating the relay n at the maximum short circuit current during a fault at the next downstream relay n+1 without upstream DG contribution [3]. The principle is explained with the following example shown in Figure 5 and Figure 6.

With the conventional grading principle, the relay 1, relay 2 and relay 3 are coordinated at the maximum short flowing through the one in the downstream. That means the coordination between relay 1 and relay 2 happens at the maximum short circuit current flowing through relay 2. This maximum short circuit current is reached if both DG2 and DG3 are connected to the network.

The new grading principle is coordinating the relay 1 and relay 2 at the maximum short circuit current without the feeding from DG2. The reason is: if there is a fault next to relay 2, the short circuit current flowing trough relay 2 is contributed by both network and DG2, while the current detected by relay 1 is only from the contribution of network. In other word, the short circuit current contributed by DG2 only flow through relay 2. Therefore, there is no need to consider the short circuit current contributed by DG2.

This grading principle lead to significant shorter delay times ensuring selectivity simultaneously for both Ring networks with numerous subunits and converter connected DG and radial network with direct connected DGs. With this new method, the benefit becomes the more obvious the higher the number of subunits which is typically for networks with DG Units like large-scale wind farm.

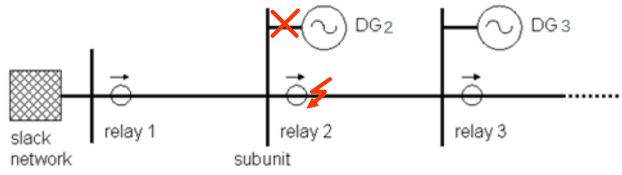

Figure 5: Example of DG networks.

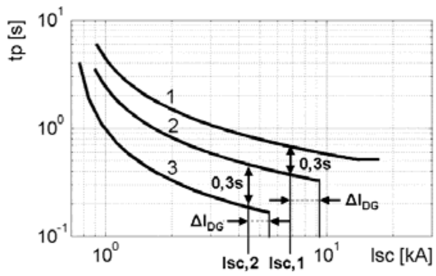

Figure 6: Grading curves in radial networks with DGs

REALIZING PROCEDURE

Flow chart of grading procedure

The general procedure of overcurrent protection grading is shown as the flow chart in Figure 7. The grading path is selected at first. The relays are set and coordinated from bottom to upstream according to the sensitivity and selectivity and the maximum operation condition of the protected equipments. The boundary conditions are checked then. If the boundary conditions are violated, the message will be recorded, and the adjustment procedure will be started.

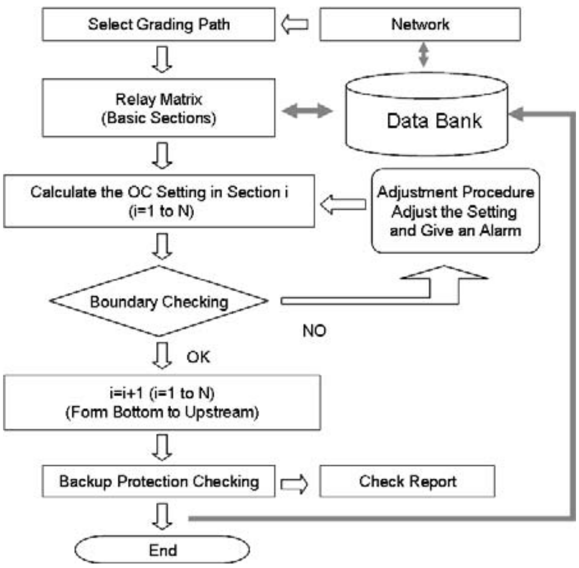

Figure 7: Flow chart of grading program

This method is like building blocks. The path is divided into different blocks at first. Then these blocks are handled one by one and finally built together.

The new approach is implemented as extension tool in software SIGRAD™.

Boundary checking

After the setting calculation, it must be checked whether the relay can protect all equipments in its section from damage or not. Beside this, the motor start up curve and other boundaries should also be checked. This is because in some special cases, the calculated relay setting value can not be reached due to the relay setting rang. Therefore it is necessary to perform the boundary examination for all constraints from the protected equipments.

The damage curve checking are performed with two algorithms as shown in Figure 8. The first one is used for checking whether the relay is below the damage curves of cable, overhead line and reactor, while the second one is used for the rest.

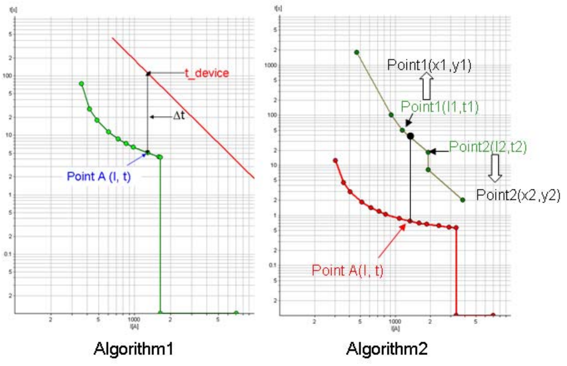

Figure 8: Two checking algorithms.

Adjustment procedure

The adjustment procedure is started if the relay fails to protect the equipment from damage. The adjustment procedure is based on the practical experience of coordination.

The first measure is to adjust time grading time of relays adjacent to HV and LV side of transformers. The grading time between these two relays can be decreased to 0.1 second with a time step of 0.01 second.

If the first measure does not work, as the second measure, the same procedure is performed for the relays on the both ends of feeders.

The last measure is to perform the same procedure for all other relays but with minimum 0.2 second grading time.

Through this way, the recommended grading time is shown. If the grading time is decreased to the limit and the problem still exists, a warning message will be given.

If the security is lost, only a warning is shown but no adjustment. The lost of security arises from the selected protection scheme and corresponding maximum limit of the relay setting range.

Backup protection checking

In the coordination process, the backup relay is guaranteed not to trip before the primary relay during short circuit faults. The backup protection checking is to analyse how much reserve a backup protection gives to the primary protection.

If the pickup current setting of the backup relay is smaller than 0.5 times of the minimum SCC of the primary relay, the warning will be shown to remind the operator.

CONCLUSION

This paper presents an advanced approach for automated and optimized overcurrent grading to face the challenges of an increasing penetration of DGs in distribution systems. The method can consider the operation limit and damage curve of protected equipment, short circuit current distribution, trip characteristics, and relay setting ranges. The proposed method is also able to define when settings must definitely be changed and when a protection scheme must be improved latest to ensure the protection system security.

This is very important for distribution system operators also from an economical point of view, only to maintain the settings and to invest in new hardware if really necessary.

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