PRACTICAL DETERMINATION OF PROTECTION SETTINGS FOR THE UTILITY HOF

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ABSTRACT

Changing of the neutral treatment might require a full revision of the protection settings in a network. For complex network configurations the determination of these protection settings is a difficult task. To ensure the functionality of the protection system sophisticated tools are needed to support the planner. At the example of the utility Stadtwerke Hof the strategy of the determination of the protection settings and possibilities of planning support by specialized software are presented in this paper.

INTRODUCTION

The networks of utilities often are historically grown. Depending on the actual pressing conditions extensions are built to solve problems on a day to day basis. Such a development leads to networks with a complex structure and a low efficiency.

Because of the introduction of the incentive regulation by the Bundesnetzagentur (federal network agency of Germany) there is an increased pressure on the utilities to improve the efficiency of their networks. To enhance the network it is necessary to step behind the operational day-to-day planning and to perform a strategic planning which looks at the actual requirements which the network has to solve and develops a reference network which would fulfil the tasks in an optimal way. Based on this reference network improvements for the existing network are proposed to improve the efficiency of the existing network.

Such a planning was performed for the network of the city of Hof in Bavaria. As this paper is focused on protection the planning steps are not explained in detail. Some of them are presented for another example in [1].

The network of Hof has 3 substations and nearly 400 stations. Its peak load is in the range of 100 MW. The network is characterised by a large number of decentralized generation units. These range from wind power plant via biomass generation to customer generation plants.

One of the outcomes of the planning was that the neutral treatment should be changed from operation with arc suppression coils to low impedance grounding. With that change the fault currents for a single phase to ground fault increase from a few Amperes to short circuit currents in the range of KA. This requires a complete revision of the protection system. Such a revision was done for the network of the city of Hof and is presented in this paper.

NETWORK REPRESENTATION

The main task of an electrical network is to supply the loads and to absorb the power from decentralized generation units. For the planning of a network therefore the spatial distribution of the loads and the generation units forms the most important boundary conditions. Therefore for the planning work a semi-geographical representation of the network is needed (for an example see figure 1). Such a representation shows the spatial distribution of the loads and the approximated routing of the lines. In such a representation it is easy to identify areas in which the network needs enforcement, rings which can be increased, switching stations which can be removed and so on.

Figure 1 Semi-geographical network representation with different supply areas

The disadvantage of the semi-geographic representation is that the electrical structure of the network is very difficult to see. The electrical network structure is the most important boundary condition for the determination of the protection settings. Therefore it is necessary to have a schematic representation of the network (for an example see figure 2). In such a representation the lines follow orthogonal routes. The drawn length of the lines and the distance between stations is totally independent of the actual lengths and distances. Protection paths can be identified easily. Such a presentation can be created by suitable network calculation software automatically with different algorithms ([2]). It could look different to the manually drawn map however, but the user can influence it or only pick out a special area of the network.
MODELLING OF PROTECTION

The protection devices were added to the model by placing them directly at the start or at end of the lines. Libraries are needed with an extensive collection of models of protection devices for overcurrent and distance protection from a wide range of manufacturers to be able to handle a wide range of planning tasks.

Protection simulation was applied to identify unselective settings for primary and back-up protection.

NETWORK CALCULATION

For the determination of the new protection settings the load flow currents and the minimal fault currents have to be taken into consideration for the worst cases. To determine the zero sequence impedances measurements have been carried out.

It is necessary for the evaluation of the protection settings to identify areas in which the minimal fault currents are too low and therefore the overcurrent pickup of the distance protection cannot be used. Instead under-impedance pickup has to be selected. In the schematic diagram such areas can be easily marked (see figure 3 for an example, critical stations marked in red).

SETTNG OF PROTECTION

The settings of the distance protection devices can be calculated automatically by suitable network calculation software. For this calculation different setting strategies are available, like linear grading part or imperative selectivity. But the planner also can calculate and set the values manually, which might deliver better results for special network structures or operating conditions.

For the network of Hof the following basic concept for the setting of the distance protection devices was used:

Time grading:
- $t_1 = 0.1$ s
- $t_2 = 0.4$ s
- $t_3 = 0.7$ s
- directional distance-independent backup time: $t = 0.7$ s
- non-directional distance-independent backup time: $t = 1.0$ s

Zone grading:
- 1st zone: 90% of distance to next protection device or customer protection
- 2nd zone: 120% of distance to next protection device or 90% of (distance to 1st protection device plus 90% of distance to 2nd protection device)

For special configurations in the network different settings were used. The impedance increment caused by intermediate infeed by decentralized generation units was considered. The values $X_0/X_L$ and $R_0/R_L$ were determined individually for all paths depending on the results of the measurements and the zero sequence data available with the network planning department of Siemens.

The same grading strategy was used for the protection against phase faults and for the protection against earth faults as far as possible. Different current values were set.
for the phase and the earth fault protection.

For the protection devices of the decentralized infeeds the setting was chosen such that a fault within the generation unit is switched off immediately. If a fault occurs in the network the generation unit will continuously feed the fault for 0.7 s until is switched off, to allow the distance protection device to clear the fault in the 1st or 2nd zone. This avoids a disconnection of the decentralized generation units during each fault which occurs in the network.

PROTECTION OF THE SUBSTATION BUSBAR AND TRANSFORMERS

For a single phase fault the fault current consists of equal portions of currents in the positive, negative and zero sequence system. The positive and negative sequence currents are delivered by the transformers (which have a delta winding or an ungrounded star winding). The zero sequence system is delivered by the grounding transformer which is located in the substation. The network operator has to ensure during operation that always the grounding transformer is operated at the same busbar than the according power transformer. Otherwise the network will be operated with an isolated neutral.

If the fault occurs somewhere in the network the current contributions of all three systems flow through one line and together form the fault current which is detected by the responsible protection device.

The situation becomes more difficult if the fault occurs within the substation. In this case the positive and negative sequence currents are delivered by the power transformer from one side to the fault. The zero sequence current is delivered by the grounding transformer from the other side (see figure 4). Only the current through the arc at the fault consists of all three sequence systems. The currents in the lines (which only can be measured by the protection devices) consist only of parts of the fault currents. The protection devices between the grounding transformer and the fault location measure only the zero sequence current (which is 1/3 of the fault current, in Hof app. 600 A). The protection devices between the power transformer and the fault location measure only the positive and negative sequence current (which is 2/3 of the fault current, in Hof app. 1200 A).

The rated current for the 40 MVA transformer is about 1150 A. This is nearly the same as the fault current. Therefore based solely on the magnitude of the current it is not possible to distinguish between a normal load situation and a fault.

Figure 4 Fault situation at busbar

This problem can be solved by an interlocking mechanism. If the protection device in the grounding transformer sees a fault current and at least one of the outgoing protection devices also then the fault must be in the network and the outgoing device will clear the fault. If the protection in the grounding transformer sees a fault current but none of the outgoing protection devices then the fault must be at the busbar or between busbar and incoming transformer. In this case the incoming transformer is switched off.

DOCUMENTATION OF PROTECTION SETTINGS

The protection settings can be documented in numerical form for each protection device or directly in the network model in graphical form as illustrated in figure 5. The settings of all protection devices can be documented in different relay specific reports using the reporting function of a suitable network calculation program [2].

For the distance protection it is necessary to see the grading paths. They are documented as grading diagrams. Besides the protection devices in the grading path downstream the traced relay it is also possible to see the zones of relays looking towards it, e.g. the unidirectional tripping time and in addition overcurrent time relays in outgoing path to industry. A combination of distance protection relays and overcurrent time relays can be put into the same diagram, if necessary. All diagrams can be integrated into the network scheme as interactive diagrams, which will update, if the settings are changed. In figure 5 an overview for a grading path together with the input data of the relays and the grading documentation of a complete path are given as example.
Documentation Grading Path 1

Figure 5 Example of grading path with interactive diagrams in PSS®SINCAL

PROTECTION SIMULATION

In complex networks a simulation of the protection behaviour for critical cases can help the planner to make sure the protection system behaves as planned under these circumstances.

This simulation takes the load flow condition into consideration as well as the distribution of the positive, negative and zero sequence system currents in the network. Such a simulation can identify pitfalls especially for single phase to ground faults in networks with low impedance grounding. Decentralized generation units which are distributed in the system might contribute currents in the positive and negative sequence which can be in the range of the load currents or higher, if there are faults in different feeders in the network. It also can be investigated what happens in the network, if protection devices fail.

The results show all protection devices which picked up and which dropped according with the measured currents and impedances for a sequence of time steps.

CONCLUSION

In this paper the steps to perform a full revision of the protection settings of all protection devices in the medium voltage network from the utility Hof are described. This revision was caused by the change of the neutral treatment. Such a revision might lead to some unexpected problems caused by the existing protection infrastructure. Some of these pitfalls and ways to recognize and to solve them are presented in this paper. Because of the complexity of the problem it is illustrated how software tools can support the planners during the determination of protection settings and help to improve the documentation quality in the complete project.

REFERENCES
