DEFINITION OF DG PROTECTION PLANNING METHODS FOR NETWORK INFORMATION SYSTEMS

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ABSTRACT

The amount of distributed generation (DG) located in distribution networks increases rapidly. This may have certain impacts on the traditional protection methods. To ensure safe and selective operation, these impacts should be taken in to account and included when planning DG interconnection. The distribution network operators (DNOs) are increasingly facing the challenges related to DG. At the same, needs for developing the planning systems for DG interconnection purposes have been observed.

This paper describes the network protection impacts of DG and the typical tools applied for network planning. The definition of protection planning functionality will be stated. Requirements and development needs for the information system in which the methods are to be implemented are also discussed. Finally, the future work to be performed under project ADINE co-funded by European Commission will be outlined.

INTRODUCTION

DG can affect the traditional feeder protection in numerous ways. It can result in totally undetected faults or delayed relay operations. On the other hand, it may result in unnecessary relay operations. It may also disturb fast autoreclosings or result in safety hazards during earth faults. DG can also remain feeding a part of the network as an island without a connection to the main power system.

DNO is typically using dedicated planning tools for planning and maintaining their networks. In Nordic thinking these planning functions are highly integrated to network information systems (NIS). These systems are typically based on steady-state calculations and rms values. This has been adequate for network planning purposes.

The present experience is that protection related problems are increasing together with the amount of DG installed in networks. New solutions are thereby anticipated for DG interconnection planning. Typically DNOs want to use their daily used planning tools instead of running dynamic simulations or performing complex calculations. Thereby one challenge can be seen in bringing new features to planning tools for DG installations. DG planning in daily-used planning tools would offer more efficiency to DNO's planning activities.

NETWORK PROTECTION IMPACTS OF DG

The traditional methods applied in distribution network planning and operation are based on unidirectional flow of power and radial structure of the network. Short circuit currents are assumed to flow downwards, which enables relatively simple protection schemes.

The introduction of DG can change this situation significantly. The power flows and fault currents may have new directions or at least modified amplitudes. Thus the whole distribution system becomes more active and shares some characteristics with transmission networks. The protection problems can be shared to four categories:

- **Sensitivity problems**. The operation of feeder protection may become disturbed by the contribution of DG. This may result in undetected faults or delayed relay operations and further in safety hazards or damages. Delayed fault detection may also cause instable operation and hence unnecessary trippings of DG units.
- **Selectivity problems**. DG may result in unnecessary disconnections of the feeder it is connected to. The DG unit itself can also become disconnected unnecessarily for instance during voltage dips or faults elsewhere in the network. These are mainly power quality issues.
- **Reclosing problems**. The fast autoreclosing sequence may become disturbed if the DG units remain connected during the autoreclosure open time. This evidently results in longer interruptions but also in damages to the DG unit. Failing reclosing can also stress the DG unit itself in the form of asynchronous reconnection when the voltage returns.
- **Islanding problems**. Islanding means a situation during which the DG unit remains feeding a part of the network without a connection to the main system. Presently, all unintended islandings must be prevented to assure the safety of the network and quality of power.

Generally, the most essential challenge is to differentiate faults requiring action from other disturbances and to operate correctly during them. For instance, differentiating faults located on DG feeder and elsewhere in the network would be very useful from the DG protection point of view.

PLANNING TOOLS APPLIED

Typically a DNO uses NIS or equivalent system for planning and maintaining the network. A modern NIS is a system integrating network data and calculation functionalities with graphical interface. Network planning, documentation and condition monitoring are typical tasks performed with NIS. The main objective is to combine technical and economical aspects of network planning. NIS is typically applied in most network planning tasks. For instance network configuration, construction or investments can be planned with NIS. According to the Nordic thinking NIS is highly integrated with other information systems and includes many calculation functionalities. Figure 1 shows typical functionalities of NIS.

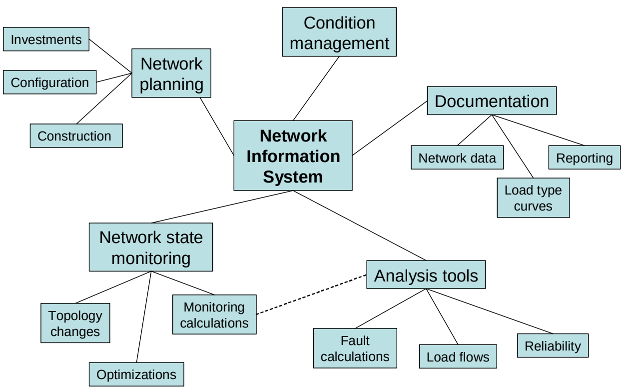

Figure 1. Typical functionalities of a modern NIS system.

Typical NIS network calculation is based on steady-state calculation and rms values. The calculation results are often presented as listings or graphically on map. Short-circuit and earth fault analysis are often performed for whole feeder or whole substation. However, fault analysis for meshed network is performed for one fault location at a time. This feature is to be used in the planning procedure as well.

Present state of studying DG impacts in NIS environments

The calculation methods applied form the greatest challenge against using NIS for DG studies. As mentioned, NIS typically means steady-state rms calculations for short-circuits and earth faults. Since the behavior of DG is highly dynamical, it is obvious that the fault situations can not be studied accurately in all cases. Presently, the DG units may be modeled mainly as a constant short-circuit source in fault analysis. With correct data this can be considered adequate for modeling larger synchronous generators. However, as a majority of new DG units is equipped with converters or modern generator types, more extensive generator modeling is needed.

Adding DG to a distribution feeder evidently changes the radial operation to as meshed one. Possibility of calculating meshed networks has not been self-evident in NIS systems. However, such solutions have been developed and they exist in some commercial systems as well. The increase of DG emphasizes the significance of managing meshed networks.

It must also be noticed that DG must be included in all other calculations performed by NIS. This means all regularly performed routines or listings after the interconnection process.

DEVELOPED METHODS

Different methods for enhancing the protection planning process for new DG unit have been developed. These methods have been planned to operate as a part of modern NIS. Figure 2 illustrates the methods as a block diagram. The planning procedure seeks to perform all required studies, whereas calculation extension seeks to offer more accuracy to the results and requirement graph seeks to present the output of the procedure in a clear manner. The methods have been presented in detail for instance in [1] and [2]. This paper focuses on integrating the functions in NIS system.

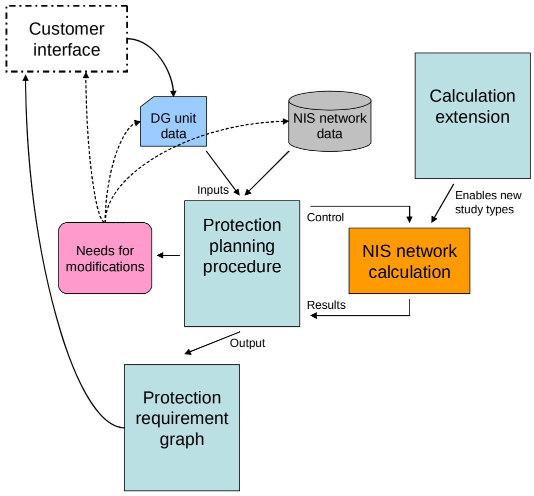

Figure 2. Diagram presentation of developed methods.

The DG protection planning function is meant to be called from NIS. DG unit data is quoted from the user and network data is obtained from NIS database. The procedure calls normal NIS network calculation and gets the results as an output from the calculation. The procedure continues to go through all necessary studies and detects needs for modifications. These needs are then forwarded to the customer and/or DG unit or network data are modified. Once the procedure has been gone through, the requirement graph can be formed through saved results. The calculation extension is a separate method which increases the accuracy of the network calculation.

DEFINITIONS AND REQUIREMENTS FOR NEW FUNCTIONALITIES

As a basis for the studies conducted, certain requirements are given regarding the background data. It is assumed that:

- Data for the network and for the DG unit is available and adequate. The properties of the generator are of great importance.
- Proposed location of DG unit is known.
- DG protection techniques that are available and/or to be used are known.
- Feeder protection has been properly set prior conducting the studies.

In liberalized energy market the DNO has practically no possibilities to affect the location, size or type of new DG units. Instead, the location is dominated by primary energy resource, owning of the land, infrastructure, environmental laws, etc. Thus developed methods are intended for the situation in which the location, size and type of new DG unit is proposed to the DNO instead of calculating the optimal location of DG.

Certain requirements are stated for the NIS environment, in which the methods are to be implemented:

- DG unit must be properly included in load flow and fault calculations. This means practically meshed network analysis and is basic requirement.
- Fault calculation should apply realistic before-fault voltages instead of constant values. This would increase the accuracy of fault analysis. Different standards [3] recommend using a constant busbar voltage in fault analysis, however the presence of DG changes the situation and realistic values could thereby be more useful.
- DG protection needs to be modeled; at least for overcurrent and voltage, preferably for frequency . Overcurrent can be modeled with normal feeder protection, however overcurrent acts often mainly as backup protection. Voltage and frequency are the most important protection factors.
- Generator modeling at least as constant fault current source. When this requirement is fulfilled, the accuracy can be increased with calculation extension methods for all generator types.

Practical implementation

The practical implementation of the developed methods in a commercial NIS requires development. As a basis, a suitable function dialogue must be created. In this dialogue it is essential to collect adequate data for the DG unit and its equipment as well as for the planned location of DG. A simple function for calculating the short-circuit power in the planned connection point would also be useful as an evaluation of the DG unit versus the short-circuit power in the connection point is often recommended.

The protection planning procedure has been planned to perform analysis point-by-point. Thus the fault analysis for meshed network needs to be looped for processing through feeders. This should be easily implemented by using the existing feature.

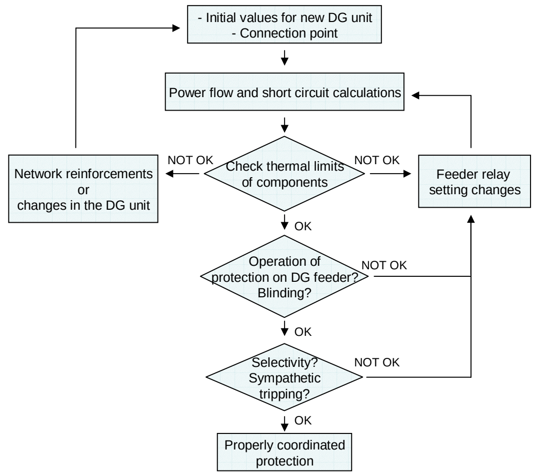

Figure 3. Simplified flow chart for the planning procedure.

One of the most important developments will be the calculation of fault-time voltage in DG connection point. This is necessary for studying the operation of DG voltage protection. This will also be of importance when studying the possibility of nuisance trippings during voltage dips. A similar procedure for calculating the fault-time frequency in DG connection point would be very useful as well. However, managing frequencies in NIS environment will be challenging. Even more difficult task would be assessing the operation of loss-of-main detection techniques such as rate of change of frequency (ROCOF).

As different fault locations are processed, there is an evident need of saving the results in suitable data structures. Saving as well as the data structures used is purely programming related issues, but the results to be saved must be defined in advance. Fault currents need to be saved for all feeder relays as well as for DG connection point. Additionally, voltage in the DG connection point needs to be saved for all studies. Frequency would be preferable as well as described earlier.

For all the results mentioned, the operation times of relays must be analyzed to assess the operation sequence of protection devices and to detect false operations. The operation times can be saved during the procedure together with above mentioned results. The operation sequences can also be analyzed completely afterwards based on the saved results.

Fault calculation development

The idea of NIS calculation extension mentioned earlier is based on repeating fault calculations and modifying generator values between these iterations. This is made in order to model dynamic behavior of generators instead of steady-state rms calculation. A simple estimate of the generator's impact can thus be formed. In earlier studies [4], four iteration rounds was observed to increase the accuracy of fault calculation. The method has been described in detail in [1] and in [4].

This new kind of fault calculation could be implemented with relatively small modifications. A simple function for repeating the fault calculation as well as for modifying the generator values will be needed. Between the iterations there is also a need to open breakers in the calculation model as necessary. As the method uses certain factors for calculating the modified values, a dialogue and data structures will be needed for setting these factors.

At this phase it is also possible to save the fault values during each time step. This would enable analysis by the user afterwards. The accuracy of such repeated calculation is not meant to be comparable to simulations. However, as the time-dependent values are easily available, they can be saved during the calculation.

The most important calculation development will be a new kind of fault analysis which calculates the operation times of different relay types according to the repeated calculation. For instance relay operation delays can be assessed. Such feature has not been used in NIS systems earlier due to steady-state calculation.

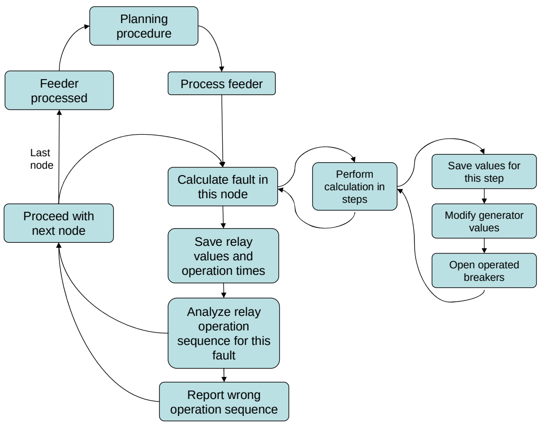

Figure 4. The calculation process and the relation of the repeated fault calculation.

WORK TO BE DONE UNDER PROJECT ADINE

ADINE (Active Distribution Network) is a demonstration project co-funded by European Commission. The aim of the project is to develop a new method for active network management of a distribution network. [5] Network protection as well as planning and information systems are covered in the project. Thus the presented methods are developed further under ADINE.

The practical development of the methods is performed as a co-operation of Tampere University of Technology and ABB Distribution Automation, Finland. The methods are developed for piloting and further using in ABB's commercial NIS/DMS environment.

At the present situation the definition of new methods has been started and the implementation of the procedure has begun. The first development phases will include automating the needed analysis and drawing conclusions based on the results. At later phases the calculation extension method will be added to increase accuracy. The protection requirement graph can be implemented when the process is found otherwise functional since it mainly illustrates the results of the process.

CONCLUSIONS

This paper addressed the challenges of bringing the DG interconnection planning towards practical planning tools. Impacts of DG should be taken into account during the interconnection but also later in normal calculation routines.

Studying the dynamic nature of DG in steady-state system is challenging. Some development ideas that are presented in this paper will be studied further under project ADINE. The methods do not seek accuracy comparable to simulation tools, instead they seek to introduce a time variable in traditional NIS system for improved accuracy.

The protection planning procedure is the most important function which seeks to perform all necessary studies automatically. Calculation extension method is intended to extend the NIS calculation for DG behavior and requirement graph is intended for presenting the results of the procedure in a novel way. The methods are under development and the objective is to build a functional prototype of the methods in a commercial NIS system.

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