BENEFITS OF USING TELECOMMUNICATION BASED PROTECTION WITH DG

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ABSTRACT

As the number of distributed generation (DG) units connected to medium voltage (MV) networks increases the structure of networks is changing and getting more complex. As a result the requirements for protection are getting more and more complicated and are playing an increasingly important role. Protection of DG units with traditional protection schemes causes performance degradation and in some cases sufficient protection levels may become unattainable. In this paper the issues with traditional protection are addressed. The benefits of using of using telecommunication based protection schemes with DG are presented from which the most important advantages are improved selectivity and decreased fault clearing times.

INTRODUCTION

The amount of DG connected to MV networks is expected to increase continuously. The increasing number of DG units at MV networks changes the long lasting concepts of power flow direction and network protection. The structure of distribution networks is getting more complex and is evolving towards meshed networks due to the increase of DG units connected to it. As a result the requirements for relay protection of distribution networks and DG are getting more complicated. At the same time distribution networks are transitioning towards Smart Grid. Smart Grids can be explained with active networks that can accommodate all kinds of active resources (generation and energy storages among others) embedded into the system. Generally it can be thought that all the resources connected to the network are also connected together with a telecommunication network.

Previously distribution networks have been protected with overcurrent sensing devices. With the addition of DG units and the increased complexity of networks this may not be sufficient anymore. For example adding DG units leads to an interesting characteristic; multidirectional power flow. Because of this characteristic fault detection cannot be based on the assumption that the fault current originates from a single source only. This paper addresses the complications that come from adding DG to the network and brings up benefits of using telecommunication based protection schemes with DG and the surrounding network. While adding DG units to the network retain many tasks this paper concentrates only on the protection related problems. The result will show that by using telecommunication a fast and secure protection system for a network containing DG units can be accomplished. Firstly the effects of DG units are discussed. The protection related challenges for protection are specified. Several protection cases that can benefit from using telecommunication are reviewed. And finally a telecommunication based protection scheme satisfying the fault ride-through (FRT) requirements for DG units is presented.

The requirements are mainly inspected with a radial network topology. Situations that are inspected include earth fault protection, short-circuit protection, loss-of-mains (LOM) protection, fault ride-through requirements and also autoreclosing practices with DG.

EFFECTS OF DG

Considering the practices traditionally applied in the distribution network protection the addition of DG has several different types of effects on the protection system operation and design. The effects of DG on the distribution network protection also depend on the type of DG unit used. DG units can be divided into three categories: synchronous generator, asynchronous generator and converter interfaced. The first two are rotating machines with different fault current producing characteristics. Synchronous generator can sustain high fault current for longer periods of time while the fault current produced by an asynchronous generator decays very rapidly. Converter interfaced DG units have their short-circuit current producing capabilities limited to approximately 2-3 times their rated current [1], [2]. More and more of the DG units in the future are expected to be connected via converter interfaces.

The effects of DG on the distribution network protection have been extensively introduced e.g. in [3]. In this paper the focus is on the most interesting effects, which are.

- False tripping
- Nuisance tripping
- Blinding of protection
- Unintentional islanding
- Autoreclosing problems

False tripping (also called sympathetic tripping) means falsely disconnecting the DG feeder. The feeder can be tripped when DG feeds a fault on an adjacent feeder and the DG feeder protection trips due to the current fed by DG. Nuisance tripping happens when DG disconnects falsely. The circumstances of nuisance tripping can be similar as in false tripping. Blinding of protection occurs when DG is feeding fault in parallel with the substation and therefore reduces the fault current fed from the substation. This means that fault current measured by the feeder relay at the substation is reduced and this can possibly lead to slower tripping or in the worst case fault not being detected at all.

In suitable circumstances it is possible that DG remains feeding a part of the network without a connection to the main grid. This situation is called unintentional islanding and it is usually not allowed e.g. due to safety reasons. Thus a specific protection method is required to prevent this.
Autoreclose is a great way to decrease supply interruptions caused by faults. According to [4] up to 80–90 % of overhead line faults are temporary and can be removed with autoreclosing. Using autoreclosing with DG may prove to be problematic. DG can cause autoreclosing sequence to fail by maintaining voltage and therefore fault arc at fault location. Therefore, the voltage dead time decreases and fault arc has less time to extinguish. Furthermore, DG can cause out of phase autoreclosure which can even lead to damage to equipment – higher stress on equipment because the reclosing is done against fault. However, autoreclosing is generally not reasonable in cable networks as faults in it are usually insulation faults and almost always permanent [4].

REQUIREMENTS FOR DG PROTECTION

Unintentional islanding is a state that must be avoided and cleared as soon as possible. There are different methods and three main categories of LOM protection. The three main categories for LOM detecting methods are; passive, active and telecommunication based methods. Passive methods rely only on measured local information e.g. voltage and frequency. From those measurements other commonly used passive methods have been developed which include rate of change of frequency (ROCOF) and vector shift (VS) [5]. Passive methods have, however, a non detection zone (NDZ) that with unfavorable conditions delays or even prevents LOM protection from detecting LOM events. This can happen when there is no power mismatch within the formed island and therefore there is little to no variation in voltage or frequency. The size of NDZ varies with protection method used. It is considerably smaller with ROCOF or VS methods than it is with more traditional under/over-voltage and under/over-frequency based methods. The NDZ can also be made smaller by using strict protection settings but this makes the protection more vulnerable to nuisance tripping of DG units.
Active methods try to influence the state of the network with small adjustments and monitoring the response. With islanded network the response will be greater and can be detected.
The third category is telecommunication based LOM protection. Commonly used methods are transfer trip and power line carrier based methods. One example of telecommunication based application is given in [6], where a telecommunication link between modern relays is used to transfer GOOSE messages to be utilized for transfer tripping when necessary.

FRT requirements for DG have been developed in order to secure power system stability during fault conditions. This obliges the DG units to support the grid during fault and abnormal network conditions and to prevent unnecessary disconnection of DG units due to faults. Fig. 1 represents FRT profile given for synchronous generators connected to voltage levels below 110 kV by [7]. Similar requirements apply for frequency as well. On the other hand, when the fault is at the feeder where DG is located, the DG should be disconnected as quickly as possible and it is possible that FRT requirements in the right circumstances prolong the time needed for DG disconnection.

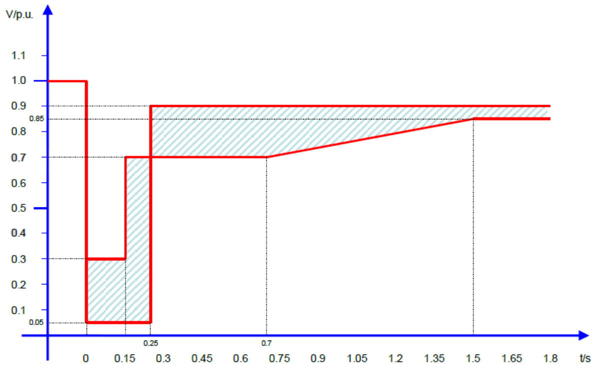

Figure 1. FRT profile of a synchronous generator unit connected at voltage levels below 110 kV [7].

TRADITIONAL NETWORK PROTECTION

The performance of traditional protection schemes without telecommunication is examined in cases that can be achieved in radial networks as shown in Figure 2. Figure 2 also illustrates one possible telecommunication connection between devices when telecommunication based protection is used.
The use of overcurrent protection with DG can be compromised with small short-circuit current producing capability of the DG unit. In this case the overcurrent protection does not necessarily detect the short-circuit current produced by the DG. Alternatively undervoltage protection can be used but disadvantage of this is that in some cases the operation can be delayed and faults at adjacent feeders can also be detected.
U_0 based protection can be used for detecting earth faults but in addition to detecting earth faults at its own feeder the DG protection also detects earth faults at adjacent feeders. In order not to unnecessary trip the DG units from earth faults in adjacent feeders the earth fault protection must be time delayed to achieve selective tripping. What this means is that at the same time earth faults at the DG feeder have longer clearing time.
Faults at an adjacent feeder may cause the DG feeder protection to trip when DG unit feeds the fault. In [8] it is said that false tripping can be avoided by coordinating the operation times of feeder relays. Faulted feeder is tripped faster than the DG feeder. A common practice is to use

similar time settings for all feeders and changing this may not always be possible [8]. False tripping can also be prevented by using directional overcurrent protection at DG feeder.

While the main aim of autoreclose is to remove the fault by applying as short supply interruption as possible there must still be long enough voltage dead time for the fault arc to extinguish. This in turn sets requirements for fast disconnection of DG units during the dead time of autoreclosing sequence. If the DG protection detects the fault it should operate simultaneously with the feeder relay in order not to decrease the actual dead time. This, however, may not be possible as overcurrent, undervoltage or U_0 based DG protection may not operate fast enough. If the tripping of DG is delayed then the dead time of feeder relay autoreclosing sequence must be increased that the voltage dead time is long enough. Moreover, if DG disconnection is delayed the time that fault arc exist is increased and likewise increases the risk of turning temporary faults permanent. Similarly having unsuccessful autoreclosing also increases the chance of permanent faults.

It can be generalized that to achieve selective tripping and avoid false and nuisance tripping the DG protection must have longer time delays than feeder protection. Because of this the successful use of autoreclosing becomes complicated. Further problems may arise if multiple feeders have DG connected.

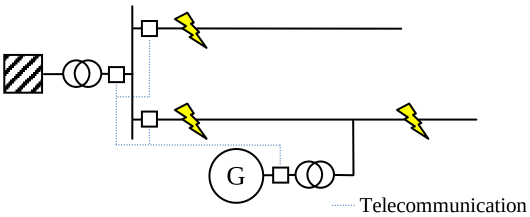

Figure 2. Illustration of the examined network.

BENEFITS OF TELECOMMUNICATION

Protection of DG and the surrounding network can gain improved selectivity and fault clearing speed from telecommunication based protection schemes. The telecommunication connections between devices can be such as is depicted in Figure 2.

False tripping of DG feeder can be prevented with blocking of the feeder protection when fault is detected at an adjacent feeder. Likewise, nuisance tripping DG can be prevented with similar blocking scheme only this time the DG unit protection is blocked.

For faults detected at the DG feeder the DG unit is intertripped simultaneously when feeder protection operates to disconnect the feeder. Advantage in fault clearing times can be observed for example comparing the fault clearing times of traditional U_0 based earth fault protection and telecommunication based intertripping scheme. The time needed to clear the fault with U_0 based protection with all the delay can take 500 ms or even longer. With a scheme where DG is intertripped when DG feeder protection detects and trips the feeder from an earth fault the fault clearing time consists only of relay operation time, data transfer delays and circuit breaker operating times.

Blinding of protection could possibly be solved by using differential protection. The tripping limits for differential protection would be needed to adjust according to largest possible load on the feeder. Another possible solution would be to install a sectionalizer at a suitable location and create new protection zone from the area susceptible for blinding.

Using telecommunication based LOM protection it is possible to completely avoid NDZ which is characteristic for all passive methods. There are various telecommunication based methods for example a power line carrier based method where substation sends a signal using power lines as media. In normal operation the signal is received at DG location but when the network is islanded the signal is lost and that can be used as an indicator for LOM protection [9]. Another method would be to use dedicated telecommunication media and send a transfer trip signal when the feeder circuit breaker operates.

The possibility of controlled island operation (microgrid) sets completely new requirements for protection. Protection of microgrids could also benefit from telecommunication based schemes as has been proposed e.g. in [10].

The speed of telecommunication has big effect on the protection and to the functions that can be achieved with telecommunication based schemes. Telecommunication signal transfer delays have been studied in [6], where it was concluded that device-to-device data transfer delays with GOOSE messages including the actual data transfer as well as the data processing are 30 ms or less.

In closed ring networks the time needed to clear faults increases. No considerable benefit is gained from using telecommunication unless all the IEDs are connected and use some method capable of determining the direction of fault relative to the device. Further in this case the protection system must determine the faulted zone. One example of method like this for microgrids has been presented in [11] but can be expanded to cover ring networks operating connected to the grid.

FRT

Power system faults cause the RMS voltage to decrease momentarily. DG unit protection detects this decrease while DG units should not be disconnected during temporary network faults and this is one of the reasons FRT requirements have been developed. Another reason is that with the increasing number of DG units connected it becomes more and more important for DG units to support

the grid during faults.
LOM protection can incorrectly detect power system faults such as faults at an adjacent feeder as unwanted islanding. In situations like these FRT requirements prevent nuisance tripping of DG. On the other hand when the conditions are inconvenient genuine tripping of LOM protection during unwanted islanding can be delayed by FRT requirements when voltage and frequency stay within FRT limits. DG units can be disconnected only after the requirements set for disconnecting in FRT requirements are met. Therefore, the NDZ of passive LOM protection is widened by the duration of FRT and can result in delayed tripping of DG. In particular the use of autoreclosing is again difficult due to the delay caused by FRT requirements.
Problem with passive detection method lies with the difficulty of discriminating between e.g. real LOM situation and fault at an adjacent feeder. Furthermore, the NDZ of passive protection prolongs fault clearing times. With telecommunication based scheme the problems can be solved. Telecommunication based schemes can accurately locate faults to a zone or feeder. When fault is detected at a zone with DG the FRT requirements can be bypassed and the DG intertripped. If fault is detected at e.g. adjacent feeder or zone this enables a possibility to widen the FRT requirements if necessary. Further the DG can be intertripped every time when LOM situation occurs. One clear advantage to this method is the ability to use fast autoreclosing without fear of it failing due to connected DG.

CONCLUSIONS

This paper addressed some of the important issues faced today with traditional protection and presented means to overcome these issues with telecommunication based protection schemes. The benefits of using telecommunication based protection schemes with DG are clear: the protection is faster and it does not encounter any false operation i.e. selectivity and sensitivity of protection is improved. Furthermore, prolonged fault clearing times caused by FRT requirements can be removed and the NDZ and possibly delayed or false tripping of passive LOM protection methods can be avoided.
However, telecommunication based schemes always need traditional protection as backup since the telecommunication based protection scheme is as reliable as the connection between devices is.
Using telecommunication based protection system is one step towards Smart Grids. Ultimately the smart telecommunication based protection systems can be adaptive so that they adjust the settings and functions according to the changes in network conditions, connection status of DGs, network topology, etc. This eventually enables full integration of DG to the grid and provides means to utilize DG also in the controlled island operation of a small part of the network.

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