COMPARATIVE ANALYSIS OF ISLANDING DETECTION METHODS IN NETWORKS WITH DG

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ABSTRACT

Integration of Distributed Generation to the Power System is necessary in order to face the future supply challenges. Therefore it will increase significantly in next years. The development a bigger amount of this kind of generation creates different problems, such as islanding. To prevent islanding problems there are conventional detection methods, passive methods and active methods.

The goal of this paper is to compare some of the before mentioned methods used in Islanding Detection with the Distribution Line Carrier method.

INTRODUCTION

The actual Power System is overwhelmed by the use and demand of supply, the need to face the everyday more acute environmental problems and the availability, geographical location and provision problems of fossil fuels. This situation makes distributed generation (photovoltaic, eolic, fuel cells, micro-sized turbines and internal combustion engine generators) a very good alternative.
Thus, it seems very likely that in a near future we will have to integrate to the distribution network a significant amount of distributed generation. Under these circumstances, it is important to analyse the problems that could appear in embedded generation. One of them is the islanded operation of the system, also called loss of mains or islanding.

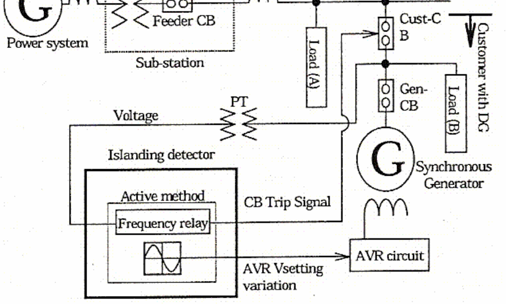

Figure 1. DG System [1]

As we can see in Figure 1., DG systems normally work connected in parallel to the main system and are directly connected to a certain load. Islanding happens when, after a fault situation on the main system, the circuit breaker that inter-connects this system with DG opens, and the distributed generator continues to provide energy to the load. This malfunction of the system can cause physical damage to system operators as well as to the power quality and the loads fed by it. That is why different protection methods are used in order to avoid it.
As well as the conventional detection methods, such as the transfer trip system, newer and more sophisticated methods are also used. Thus, there are passive methods that supervise the variation in voltage, harmonic distortion, frequency, etc. as the considered standard relays ROCOF and COROCOF. Among the most sophisticated, we have active methods which are able to detect islanding even under perfect equilibrium circumstances, such as REED relays, reactive power fluctuation, inter-harmonic injection, load fluctuation, etc.
However, these are not fully completed technologies and present some problems which can be solved using Power Electronic devices and Information Technologies, such as the Distribution Line Carrier (DLC) method. This kind of detection would suit fine to the concept of the future Smart Grid. This future grid would make use of Information and Telecommunication technologies to optimize the network capacity, improve its reliability and guarantee the power supply. This grid should also be capable of autohealing, offering excellent security standards, supporting DG, improving throughput and it should also be consumer adapted.

DETECTION METHODS

We can split islanding detection methods into three categories; the traditional, passive and active methods.

Traditional Methods

Among the traditional ones, the transfer trip system transfers a signal to trip a circuit breaker positioned on the DG side, thus preventing it from feeding the load. This signal is transferred when the circuit breaker that causes the islanded operation trips, through a dedicated line. If the fault that causes the islanded operation comes from a higher system, then islanding will not be detected.
Similar to the transfer trip system is the SCADA one. In the SCADA system, the status of the circuit breakers liable to

cause an islanded operation is monitored. If their status changes, a signal is sent to the circuit breaker on the DG side to prevent islanding.
The inconvenience of these methods is the high cost of the implementation processes and equipment necessary for it.

Passive Methods

Passive methods are based on the principle that when islanding happens, some important parameters of the network change, for example: voltage, current, frequency and harmonic distortion. Monitoring the changes of this parameters the islanded operation can be detected and prevented.
Usually a relay monitors one of these parameters. When the value is higher than a certain preset threshold, the relay trips to prevent islanding. The setting of this threshold value is very important for a successful detection. If it is very sensitive it may cause nuisance tripping. This means, the relay may trip even if there is no real islanding situation, because a variation on these parameters could also have a different cause, such as a sudden variation of the load. The opposite will happen if the threshold value is looser; in this case, non-detection zones (NDZ) will appear. NDZ are values of the variation of the monitored parameter for which islanding actually happens but can not be detected.
The standard device is the ROCOF relay. It monitors the rate of frequency change that happens due to an active power imbalance. The imbalance has to be about 13% and the response time shouldn't be longer than half a second. Ideal response time would vary between 200ms and 400ms. For power imbalances less than 13% there is NDZ. The most conservative case is a deficit of power in a reactive load. The COROCOF relay is a newer version of the ROCOF that compares the rate of change of frequency at the generator with the one in the rest of the power system [1].
The standard over/underfrequency and over/undervoltage relays can also be used for islanding detection. They work on the basis that an active power imbalance between the power demanded by the load and the one given by the system causes a voltage shift. Then, voltage decreases in case of a power deficit and increases in case of power excess, tripping the undervoltage and overvoltage relays respectively.
In case of inductive load, reactive power is positive and it would have to be compensated from the grid. When islanding happens, frequency should increase to keep Qload=0, tripping the overfrequency relay. In case of capacitive load, the way to equal Qload to zero is a decrease of ω, and that would trip the underfrequency relay.
Another device is the vector surge relay. This relay works on the principle that there is a voltage drop between the voltage supplied by the generator and the voltage at the load due to the reactance of the generator.
Thus, there is a phase difference between both voltages. In case of islanded operation, the load will need more or less power than the one supplied by the generator. Depending on the deficit or excess of electrical power the phase angle will increase or decrease. When this happens, the frequency of the terminal voltage changes because so does its period.
Finally, the harmonic monitoring method can also be used, because of the magnetic hysteresis of the transformer. It responds to islanding distorting the signal with a large third harmonic component.

Active Methods

Active methods are suitable when islanding does not affect the equilibrium of the system. Thus voltage, frequency and harmonic distortion variations are not specially significant, and cannot be used for the detection of the islanded operation.
For active detection a turbulence has to be produced from the DG to the utility's power system to make sure that voltage and frequency vary when the islanded operation begins. To create a turbulence requires time and this causes a delay in the response of the system. On the other hand, active methods do not show a non-detection zone and detect an islanded operation almost in all cases.
One of the most popular active methods is the reactive Export Error Detector Relay (REED Relay). This device makes the DG system inject a level of reactive power flow at the relaying point. This reactive power can only be maintained as long as the DG and the utility grid keep their connection. In the moment of islanding, the relay detects the change of the reactive flow and trips. This method has a certain impact on the distribution network, because it is necessary that the reactive flow at the node keeps almost constant.
Another method is the system fault level monitoring. The system source impedance is measured from the short circuit current and a shunt inductor is connected through a thyristor switch. At this moment, the voltage variation is monitored. The cost of this system is higher and the response has a certain delay.
The inter-harmonics injection method consists on injecting non-integer harmonics to the power system. The susceptance of the power system changes when the islanding begins and this response trips the relay, preventing the DG system from feeding the load. Of course this system also impacts on the power system since it injects harmonics and it could interfere with the quality of the signal [1].
However, not all active methods are applicable to every generator, as shown on Table I. In some cases, the turbulence signal introduced in the system is a voltage fluctuation, applied through an AVR in the side of the DG. In the case of the Reactive Power fluctuation method, this voltage variations cause a frequency deviation which increases when the islanded operation begins. In the case of QC mode frequency shift, the relay monitors the rate of frequency change which also varies significantly when islanding happens.

	Synchronous Machine	Induction Machine	DC sources + Inverter
Reactive power	Applicable	Not applicable	Applicable
QC-mode frequency shift	Applicable	Not applicable	Applicable
Reactive power compensation	Applicable	Applicable	Not applicable
Load fluctuation	Applicable	Applicable	Not applicable

Table I. Applicability of some active methods [1]

In the case of reactive power compensation, the turbulence is a fluctuation of the reactive power created by a reactive power compensator which causes a frequency deviation that increases in the moment of islanding. Finally, in the case of load fluctuation method, the turbulence is a load insertion at the coupling point, and the respective detection signal a current dividing ratio.
Another point to take into account is that, in case of multi-embedded generation active methods could interfere among themselves. Interferences appear even if the same detection method is used in each subsystem. To prevent major disturbances, each case should be analyzed individually.

Passive vs. Active

The main difference between passive and active methods is the principle they are based on. Passive methods work on the basis that when islanding happens some important network parameters vary significantly. Active methods introduce a disturbance that forces the power system to give a certain response that cannot be kept after islanding.
Both passive and active methods have different advantages but also present major drawbacks. As we can see on Table II, the weak points of the passive methods are the Non detection zones, the possibility of nuisance tripping and malfunctioning. The use of active methods solves these three questions but creates problems that do not appear when passive islanding is used; they may have an impact on the power system and the detection time is longer.

	Passive Methods	Active methods
Based on	Monitoring changes in network parameters: THD, voltage, frequency,	Applying disturbances from distributed resources
Detection time	Shorter	Longer
Non-detection zone	Present	Not present
Nuisance Tripping	Possible	Not possible
Malfunctioning	Possible	Not possible
Impact on the system	No	Possible, because of the introduction of turbulence

Table II. Active vs. Passive

DISTRIBUTION LINE CARRIER (DLC)

Islanding prevention through Distribution Line Carrier (DLC) is a way of preventing islanding by injecting a high frequency signal at the distribution substation [2]. This high frequency signal is able to carry information. It is also possible that the carrier is a sub-harmonic signal transmitted on the LV grid [4].
The high frequency signal is injected at the medium voltage busbar through a coupling device and it propagates immediately throughout the feeder to every point of the system including the DG end. The signal always keeps in the MV system because the transformers act as a low pass filter at the energy conversion points, rejecting the high frequency signal.
As we can see in Figure 2 a receiver is placed at the DG end through a coupling device tuned on the right bandwidth, to detect the incoming high frequency signal. When islanding occurs and the circuit breaker that ties the two systems opens, the receptor ceases to receive this signal and thus detects the islanding situation.

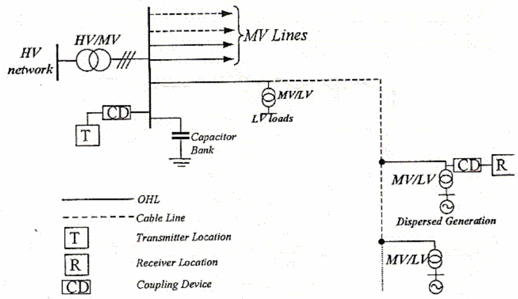

Figure 2. DLC-based anti-islanding [2]

The main problem presented by this method is the signal attenuation. The factors that contribute to the carrier attenuation are: overhead and cable line attenuation, capacitor banks, different line segments, branching, mismatching and standing wave patterns. It is considered that the signal can be transmitted in a good condition about 15 km, which means that the distance between substation and DG should not be bigger than 15km. If this is not the case, repeaters have to be used in order to preserve the carrier. These repeaters would make the system more expensive.
DLC based detection is based on a very simple principle but successes in avoiding the main problems presented by passive and active methods, as can be seen in Table III.
Conventional detection methods also avoid these problems but they are high cost solutions. DLC communications would make the best solution if they are proved cost effective.

Based on	DLC Communications
Detection time	Shorter
Non-detection zone	Not present
Nuisance Tripping	Not possible
Malfunctioning	Not possible
Impact on the system	Not significant
Applicability	All generators
Multi-embedded generation	No interferences

Table III. Advantages of DLC

Economic feasibility

The necessary equipment to develop this solution is quite simple: a transmission line for carrier signal propagation, a transmitter at the substation and a receiver at each DG end. If the distance between substation and DG exceeds 15 km, then repeaters are necessary. If the carrier is going to include any other information a modem at both ends is necessary. Also, if for security reasons this information is going to be coded a codec should be available at both ends. For the sub-harmonic carrier injection, a low cost receiver prototype design has been developed. This prototype is based on a modification of Automatic Meter Reading systems which priced on 21$ and considering it would be manufactured in large quantities (>5000), the cost would lower to 8$ [4]. Considering that the price of the receiver could be optimised and that the transmitter price could be keep on a similar price, for a system that wouldn't require repeaters, we appreciate that it is a cost effective solution. But even if it would require a more sophisticated equipment this solution could still be considered a low cost one. In the frame of Smart Grid we have to consider that the use of DLC only for islanding detection would be a waste. The technologies to carry significant amount of information through DLC are very developed nowadays and allow even broadband transmission in optimal conditions, without having a negative impact on the grid or a loss of the carrier information. Such a system requires a much more developed and expensive infrastructure and technology but its economical potential is huge, it would provide the customer with new added value services and it would help to improve the quality of the supply. Under such premises anti-islanding would become a low cost collateral solution.

CONCLUSIONS

The current islanding detection methods are still not fully developed technologies and show severe deficits. The main problems of the existent systems are the following:

1. They present important non-detection zones, which is the case of most frequency based and passive methods. In order to avoid NDZ, the risk of nuisance tripping increases against the IEEE distributed resources interconnection guide recommendations.
2. They present significant delay in the response, like some active methods.
3. Their use causes an impact on the grid which would be better to avoid, as is the case of some of the active methods.
4. Their implementation cost is very high, as in the case of some active and traditional systems.
5. In case of multi-embedded generation, some methods used on a certain system, could affect the efficiency of another method used in a different one. It is difficult to asset the impact of these interferences.
6. Not all the islanding detection methods can be used for all kinds of generation. They are applicable depending on the kind of generator; synchronous, induction or DC with inverter

As we have analyzed through the paper, almost every method could be classified into one or more of the categories mentioned above. Very interesting solutions have been developed to solve some of these problems and sometimes the combination of more than one detection method is the answer for a successful anti-islanding solution.

The aim of this paper has been to compare these different methods with the DLC method for the islanding detection. As a result we can conclude that DLC based protection is one of the few methods which solves all the problems mentioned above. Thus, it works in real time, does not present non-detection zones; the impact on the functioning of the grid is little due to the advanced modulation techniques used, multi-embedded presents no problem, receptors at DG end would be needed but a single transmitter would be enough and detection does not depend on the kind of generator used at the DG end. Also, it seems to be a low cost solution for islanding detection.

Besides, this kind of detection would suit fine to the concept of the future Smart Grid. But a detection method based on a new approach as is DLC, present some new problems that should be carefully analyzed. Some of them can be easily overcome but this would turn DLC into a higher cost solution. Nonetheless, if we see DLC not just as a mean for islanding detection but as a way of providing additional services to the customer and improving the quality of the supply, it is clear that the economical profit will still be positive even if the cost of the solution increases.

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