ANTI-ISLANDING PROTECTION OF DISTRIBUTED GENERATORS WITH REGARD TO SENSITIVITY IN A BALANCE AND POWER SYSTEM STABILITY

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ABSTRACT

This paper describes development of the methods for islanding detection. Islanding of distributed generation can appear in cases of deliberate disconnection of network parts or disconnection due to fault. This article analyses the problem of distributed generation (DG) islanding in networks where islanding is not allowed. Time duration during which DG left in islanding mode must be disconnected is defined by networks automated processes (i.e. automatic reclosure). Considering the fact that future smart grids will have even bigger degree of automatisation, now is the moment to figure out how to decrease time during which DG operates in prohibited islanding mode.

It is generally acknowledged that common passive anti-islanding protection methods are not always reliable due to the existence of non-detection zone (NDZ) in which active and reactive power of all loads and sources in the grid are close to or in balance. Active protection methods are more reliable in islanding detection, but are more complicated, slower and add additional interference to the grid. Third option is protection methods based on communication automation process devices, but such solutions require complex and expensive communication infrastructure.

INTRODUCTION

Islanding in a distribution network occurs in case of deliberate disconnection of radial parts of the network by the operating personal or caused by protection devices in case of disturbances. In both cases, it is essential to disconnect DG units for successful anti-islanding operation and prepare their synchronized reclosure in grid. Uncontrolled islanding is hazardous to personnel working on the grid. Also an unsynchronized reclosure of DG in the grid can cause damage to the DG and network equipments. Frequency and voltage supervision are used as a basic passive anti-islanding protection insuring the quality of grid parameters, but can cause long periods of islanding. Increase of DG units in the future will have a significant role in the network, thus the reliability of anti-islanding cannot be based on simple passive protection methods measuring frequency and voltage not recognizing the islanding event from the general disturbances in the grid. In order to distinguish the islanding from the regular disturbances in the network, next logical step was the development of fast and reliable anti-islanding protection methods.

Time needed to detect islanding depends on the time settings of the grid automation, namely auto-reclosing open-time settings. In our network high speed reclosure function is used in combination with certain protection functions, time of high speed recloser is 0.4 s so the time needed to detect islanding has to be beetwen 0.2-0.3 s. Next steps in grid automation are fault location with automatic line change-over and smart operations to insure optimal power flow. With the ever growing number of automated junctions in the network, it is essential to shorten the time of islanding detection, even in grid that has no high speed auto-reclosing.

The biggest problem in islanding detection is the case when DG units and part of the grid that would be in an island are in a production-consumption balance. In case of balance anti-islanding protection can only be achieved with active and communication based methods. With normal characteristics of the network with DG units, it is highly unlikely that the occurrence of perfect balance will be achieved, but the near balance probability is high. Simple passive methods are not adequate for near balance state so active methods can be used; these methods interfere with the grid parameters in order to detect islanding. In case of high number of same active methods used on a specific part of the network, it is highly probable they´ll have negative consequences due to interference of injected signals into the network. To avoid these problems, new hybrid protection methods were developed. These protection methods use specific algorithms to combine passive and active components. Opposite of these methods, with the ongoing development of in depth network communication, communication based protection methods were involved by analysing the specific junction points in the grid that determine the case of islanding.

ANTI-ISLANDING PROTECTION METHODS

DG units are basically divided into two types; DG with electronic converter and rotating machines based DG. Converter based DG produces energy and delivers it into the network by converting DC input current, while rotating distributed generation is connected directly to the AC grid. In its complex circuitry and design, converters have embedded a combination of passive and active anti-islanding methods that prove to be fast and reliable. Subsequently it is concluded that networks with rotating machines installed have difficulties in detecting islanding because they don't have any form of cost-effective active anti-islanding protection. With the difference in production over the consumption, inertia in rotating machines causes the instant changes in voltage, frequency and angle shifts. However, the same changes in the sub network are also caused by faults, disturbances, switching of large loads and sudden losses of a production unit in the same subnetwork. Installing a relay with activated passive protections and setting it to high sensitivity would cause unwanted tripping in the DG.

Passive protection methods

Most commonly used passive protection methods, that measure common physical network values which are significantly changed in case when a distributed production unit goes into islanding, are rate of change of frequency (ROCOF) and voltage vector angle shift (vector shift). Fig. 1 shows the correlation between the values φ_1 and φ_2 representing vector shift, when the production unit goes into islanding with distribution subnetwork difference in production over consumption.

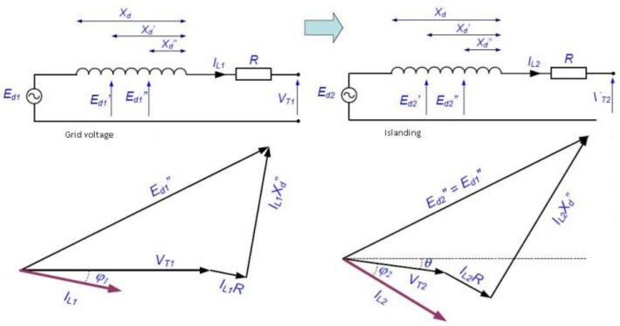

Figure 1 - Representation of values for vector shift method [11]

Relay measures the vector shift change by the voltage angle comparison at every zero-crossing and tripping if the measured parameter excites the setting parameter. Fig. 2 shows the representation of rapid change of frequency in the distributed production unit caused by islanding. Relay measures the voltage frequency and calculates the rate of change of frequency that is represented by the formula in Fig. 2, the change rate is depended of rotor inertia constant (H) and the differential of active power (ΔP) [9].

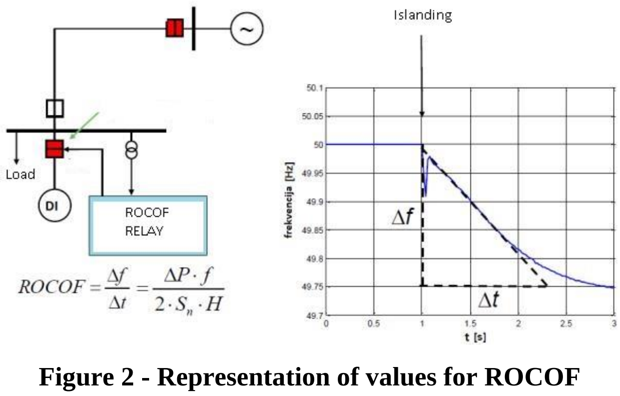

Figure 2 - Representation of values for ROCOF method

It is concluded that for these methods to be functional, there has to be a substantial power differential in the islanded subnetwork.
The setting threshold of protection relay defined non-detecting zone (NDZ), it is relative to the minimal difference in the production over the consumption in islanding state. Correct setting selection is a hard task depending on network parameters and is recommended to be checked in real network test. Through the history of developement it is clearly that the process of the algorithms upgrade was a success, but in highly automated networks they are still obsolete. Only in case of intentional power differential, these methods would prove to be a success. In order to do so correct measuring and modelling of the subnetwork would be required.

Active protection methods

Active methods are mainly used in converter based DG units. Older types of active methods used periodical signal injection and were used in subnetworks with a low number of similar production units; the greater the number of converters with similar signal injections, the greater is the signal interference, resulting with maloperations or loss of sensitivity to islanding. With the development of escalating active protection methods, we have the case in islanding that the algorithm for a small change in voltage or frequency deliberately activates injection to pushes the parameters over the setting threshold. If the production unit is not islanding, then the threshold is not exceeded because of the solid connection to the grid.

Communication based methods

Parallel with the development of active and passive methods, we have the focus on communication based protection. These protection methods analyse various parameters in network junctions that deduce the case of islanding. In order to achieve this kind of protection, there must be a substantial development of communication infrastructure. There are two mainstream data state evaluations; islanding trip command and the congregation of measured values. For example, there is an online comparison of voltage angle measured in the network junctions with PMU units. This successfully used method for the stability of transmission network is also valid for islanding detection in distribution network, but communication infrastructure is still developing for mass usage. Also in progress is the development of PLS (power line signaling) protection method as shown on Fig. 3 [8].

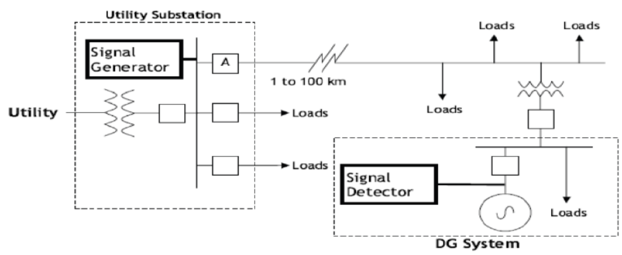

Figure 3 - DG Power Line Signaling islanding detection

This method uses signal generator that constantly injects the carrier signals across power line to all network users and islanding is detected as a carrier signal loss. The major drawback on this method are the vast investments in PLS equipment. The PLS method is mainly used outside Europe.
Communication based methods are fully effective if the communication is stable and not interrupted, alternatively there must be backup islanding protection.

DEVELOPMENT OF ISLANDING DETECTION METHODS

It can be concluded that passive protection methods are on the one hand most cost effective and simplest to implement on the other less precise to detect islanding. They are beeing constantly upgraded and improved.

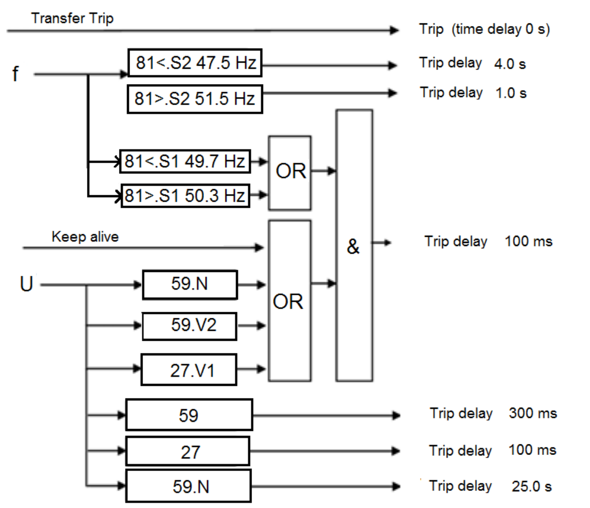

Figure 4 - IPS anti-islanding protection scheme [3]

One of the upgrade principal is the implementation of the IPS (Interference Protection System) protection scheme [3] along with frequency protection in islanding (Fig. 4). With following protections picking up 59.N-residual overvoltage protection, 59.V2-inverse overvoltage protection and 27.V1- direct overvoltage protection, the conditions for trip activation of the sensitive frequency protection are fulfilled. Benefit of using IPS protection method is the prevention of unwanted generation loss due to disturbances in the transmission grid that do not contribute to a possibility of islanding. Protection trip generated by the IPS is fast enough to be adequate in networks with automatic reclosures. The main drawback of the method is in the case when generation and consumption are near equilibrium. Voltage setting parameters are the key element for successful implementation of the method.

Advanced voltage vector shift algorithm

Advanced algorithm analyses the voltage angle in correlation with the values of voltage and frequency according to [1]. With the measurement of voltage and frequency the algorithm adjusts the voltage angle according to their variations in normal state. Algorithm detects islanding in single phase by calculating the threshold value of voltage angle and the values of U< and U> pickup states. If the pick up states are not valid, the algorithm continues to check all three phases in the next period. For method evaluation the real 21 kV model of subnetwork was developed including a substantial number of distributed generation both rotating and inverter based [1]. Setting value of voltage angle difference is 5 degrees, pick up value of U< is 0,8 p.u. and of U> is 1.2 p.u.. The method showed promising results by tripping in 50 ms for large mismatch in production - consumption up to 250 ms for small difference in production - consumption and no tripping for disturbances in higher level of network.

Islanding protection based on the combination of ROCOV and ROCOF algorithm

ROCOV islanding detection method is based on the reactive power differential due to the effect of losing the network connection. The reactive power differential causes voltage shifts in the subnetwork with distributed generation. ROCOF detection method is based on active power differential in the same manor as ROCOV method. The active power differential causes frequency oscillations in the subnetwork with DG.

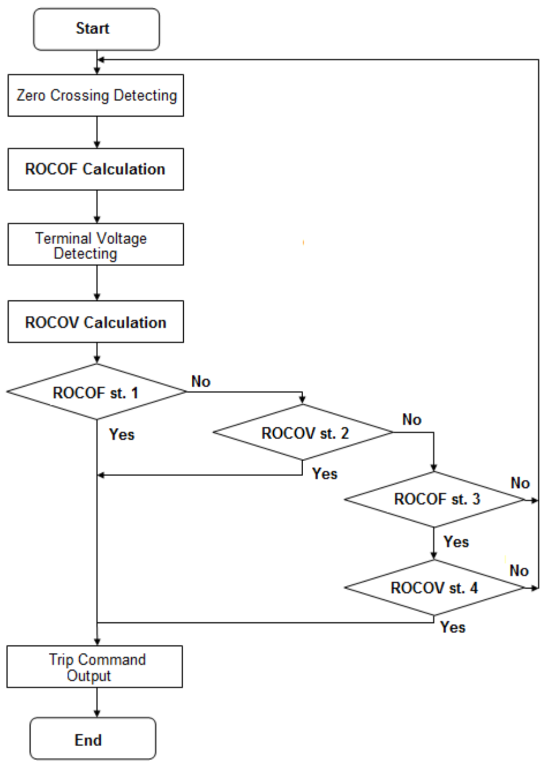

Figure 5 - Proposed procedure of the integrated ROCOF+ROCOV islanding detection method [7]

When analyzing the algorithm that combines this two methods (Fig.5) it is clear that the islanding detection is improved in order of NDZ reduction. Various analysis of this algorithm have proved that it trips, when islanding conditions are met, between 125 and 300 ms in near balance of production and consumption [7].

Smart ID devices for islanding detection

Smart ID islanding detection devices use passive methods based on the measurement of voltage and current in terms of harmonic analysis. ā and б parameters that define voltage and impedance for the network are calculated according to Thevenins model. By determining ā and б values and with the setting of ref_a and ref_b the relay determines the islanding state [2]. Smart ID relays are simple and not costly devices designed for low voltage network use. 3 relays were tested in real conditions using regulated sources and detected islanding for power balance within 4 s, while the expected time to detect islanding was up to 10 s [2].

Escalating frequency shift

Active escalating frequency shift method is used in inverter based distributed generation. When the minimum frequency offset conditions are fulfilled, the inverter injects additional amount of reactive power in the network causing changes in frequency when the distributed source is in islanding, the result is the trip of frequency protection elements. The rate of injected reactive power is defined by the relation Qinjected = k' (fn - f) [6], where (fn - f) is difference from the nominal network freqency when in islanding. Coefficient k is the parameter that is defined by the network parameters resulting in the rate of injected reactive power, the greater the k the grater amount of reactive power is needed for injecting. This method is effective even for power balance. The upside is that the number of inverters using this antiislanding method is growing.

Scheme of active network management

Invention of new stable protection systems for islanding detection in smart grids lead to innovative CANM scheme of active network management using IED units that exchange data [4]. CANM schematic includes three basic functionalities: minimisation of losses and reactive power costs, reliable islanding detection even with passive methods and adaptive auto-reclosing open- time settings (150 to 600 ms). Study of CANM's efficiency showed that all the functionalities can best be used by active control of reactive power flows. By regulating reactive power using distributed generation units and built-in compensating facilities in MV network, enough reactive power unbalance (Qunb) is achieved, in order to successfully detect islanding in real time using passive methods.

EUROPEAN REGULATIVE CHANGES DUE TO INCREASED RATE OF DG

Developed European countries with large amount of DG units in their power system encourage development of new European regulative regarding active distributive networks. Electrical protection relays based on common voltage and frequency anti-islanding method can cause large number of distributed generation units to switch off the grid during the occurrence of disturbance in the transmission network and cause possible blackouts. Examples of large networks blackouts have already been recorded, so new regulations are trying to increase stability of power system. One of the important issue is frequency ride through (FRT), for the purpose of electrical power system stability new regulations state that distributed sources shouldn't be switched off the grid with frequency protection relays for at least 30 min while frequency is in range from 47,5 to 51,5 Hz, Fig. 6. Another part of new regulations is also a part concerning P/f droop, according to which active power regulation must be activated at source when frequency reaches values between 50,2 and 50,5 Hz according to P(f) diagram, with curve gradient of 2 – 12%. For larger sources voltage-time diagrams are also defined for low-voltage-ride-through (LVRT).

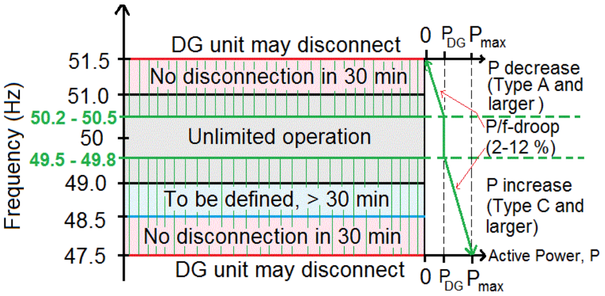

Figure 6 - Frequency FRT and suppor requirements for DG units [10]

Active power regulation on distributed sources is being used as a mean to increase stability of power system, but it's also increasing the possibility of balance during islanding operation, and as such the impact of P(f) regulation on existing anti-islanding protection is negative. Analyses of an active network with applied P(f) regulation has shown relatively small increase of NDZ in installed protection relays. With further addition of Q(U) regulation, the possibility of balance in islanding operation would be significantly increased [5], and as such would complicate application of some active methods that are used with convertor type DG units that use reactive power regulation at source. On the other hand, an article [6] shows that active method of escalating frequency shift, if used on large number of sources in a network part, can cause additional system frequency drop in case some of the sources in that network part switch off.

Although new European grid codes demand functionality of DG ride-through-fault, with islanding operation of DG being allowed, there still exists a need for reliable islanding detection in order to adjust network functions for islanding mode of operation.

CONCLUSION

Common passive protection methods can't fully protect the network from negative consequences of islanding while active methods are successfully applied mostly on converter connected generating technology. This paper describes some improvements of islanding adaptive passive protection methods, but only with additionally using communication technologies we'll be able to detect islanding, even during balanced load flow. The speed with which new methods will be developed and applied will depend on the identification of damages caused by uncontrolled islanding future on.

In order to ensure stability of the system, while number of distributed generation units in power systems is constantly increased, new European legislative with demands on distributed generation like active and reactive power regulation is developing. The effects of that new legislative are that operating conditions as the balance is much more likely to appear.

When using new methods for the detection of islanding, it must be considered that the stability of the power system must be preserved.

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