Developing of Islanding Detection Technique

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Abstract: The detection of islanding is one of the major challenges being faced in the operation of Distributed Generation (DG) or/and Mini Grid (MG). Among various methods of islanding detection techniques, this paper focuses on identification, modeling, and simulation of various passive methods that can be applied to the context of Nepal, Where DGs (i.e. Micro Hydro) are far apart from grid as well as from each other too. This paper includes Current Relay, Voltage Relay, Frequency Relay, Rate of Change of Frequency Relay, Voltage Vector Shift Relay and Positive Sequence Impedance Methods. The results show passive methods are suitable for islanding detection if there is a large imbalance between generation and load. However, if there is little or no imbalance between generation and load, most of these passive methods fail to detect islanding leading to a small non detection zone. Among different methods analyzed Positive Sequence Impedance Relay found to be suitable in context of DGs/MGs as in Nepal, when they are far apart from the grid and each other too.

Keywords: DG; MG; Islanding; LOM; Detection

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1. Introduction

The traditional model of power system is dominated by centralized generation and passive radial distribution networks. In this model mainly power plants are of larger size with coal, oil, hydro, nuclear plants etc. it has disadvantage that power has to be transmitted over long distances which not only requires huge infrastructure but also have larger transmission losses, environmental effects and security hazards (Minnan, 2010). Again the depletion of fossil fuels and nuclear waste with ever and ever increasing rate of energy demand is demanding some form of renewable, and of course, renewable are mostly available in small scales and are available near to the consumer. This fact is leading towards the development of distributed generations i.e. DG(SAMAROO, 2012), with renewable and Sometimes diesel generators operated within the premises of industry, farms etc acting as DG. Hence with the tacit advantages of renewable and distributed generations the electricity networks are in the era of major transition. Nowadays distribution networks are active with bidirectional power flow rather than stable passive with unidirectional power flow. However the active networks are proven to be advantageous, such operations are not so simple, and the detection of islanding is also one of the major problems being faced (Sarabia, 2011).

Islanding occurs when DG or micro grid system continues to energize a portion of the area Electric Power System (EPS) that has been separated from the rest of the area EPS, as shown in figure 1, such operation is harmful and also might be life threatening. If Islanding/Loss of Mains (LOM) is not detected, then the generator could remain connected, causing a safety hazard within the network. Automatic reconnection of the generator to the network may occur, causing damage to the generator and the network. And of course, it's why Islanding is not permitted in most countries. So, as soon as possible such operation should be avoided. There are various passive methods that have been practiced yet for islanding detection and protection, which includes viz. Frequency Relay, Current Relay, Voltage relay, Rate of Change of Frequency Relay, Rate of Change of Power Factor Relay, and Voltage Vector Shift Relay etc (Stråth, 2005), (A Malathi, 2014).

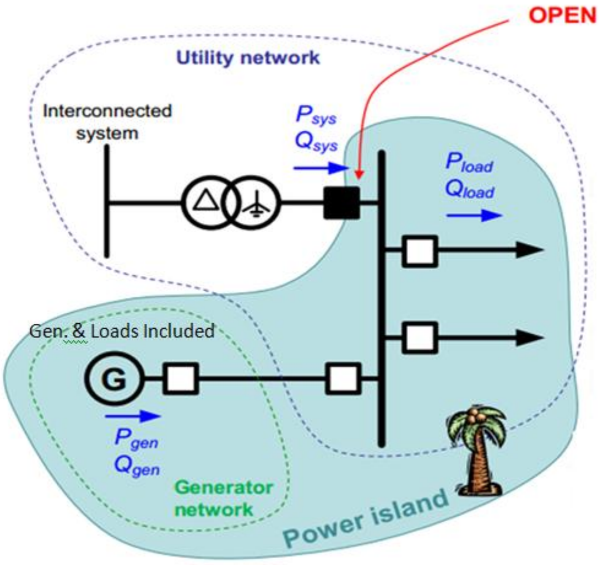

Figure 1: Islading concept(Booth, 2011)

In context to Nepal, DGs are far away from the grid; if it was in the proximity to the grid, transfer trip could be the easiest solution. But, we have DGs located at distances from the grid and from each other too, thereby possibility of transfer trip and signal transmission is almost nil. We need such method which can detect islanding just by sitting at distance from the grid. For larger DGs, it would be feasible to invest more money for islanding detection. However, for small micro hydro larger investment for islanding detection is not feasible. So, this thesis focuses on critical analysis of the available islanding detection techniques for such scenario of DG/MG.

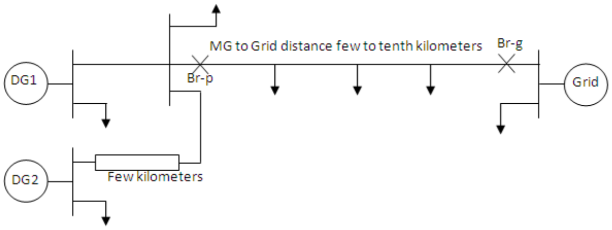

Figure 2: DGs and Grid connection showing scenario of Nepal

As shown in the figure 2, there are two DG, connected via a common feeder to the grid. Here, the breaker Br-g might get open because of any reason, subsequently the breaker Br-p has to open. Because of the distance between grid and MG the transfer trip is not possible and normal islanding detection methods might show very large Non Detection Zone (NDZ). So, the critical review of various detection techniques is essential for such scenario. Similarly, once LOM is detected the breaker Br-p will open and again the distance between DG2 and Br-p is large enough to restrict the transfer trip or conveying any message, thereby acquiring some means to tell DG2 that it is no more Grid connected or Br-p is open. So these two levels of detections first mainly for the safety reasons and second mainly for the operating plan is essential in such context.

Islanding/LOM protection should be sensitive under all possible load and generation scenarios (Xinyao Li, 2013). The most challenging scenario is when the local load closely follows the generator output both in terms of active and reactive power. Under these condition most of methods fail to detect islanding, i.e. leading to a Non Detection Zone (NDZ). It should be stable under remote faults cleared by the utility system. It is undesirable to issue a false trip as it leads to the unnecessary disconnection of the generator.

Because of these issues normal islanding detection techniques has to be critically reviewed. In this paper various passive islanding detection methods will be identified, modeled and their simulation will be performed for such scenario. Their performances will be identified under the test circuits loading conditions, results will be analyzed, and suitable method will be identified.

2. Methodology

There are various methods that have been used yet for islanding/LOM detection and protection and even more are under research. At first it can be divided into two category viz. Local and Remote, and under local methods main categorization is passive and active method. However, they have small range of non detection zone, passive method are the commonly used techniques because of their simplicity and low cost. It is worth here to discuss them individually.

Current Relay:

As soon as the loss of mains occurs then whole load has to supply by the DG/MG, if the islanded part has larger loads then it causes the over current in the system, thereby causing over current relay to disconnect the DG/MG from rest of the system. However if the load is almost equal to DG/MG generation, such relay cannot expected to work.

Voltage Relay:

Under normal condition system voltage remains at some steady state value, almost 1 p.u., however, as soon as the loss of mains occurs then whole load has to be supplied by the DG/MG. Load supplied may be larger or may be lesser than the DG/MG generation, which may cause the over current in the system causing the voltage to fall below normal range or may cause under loading causing overvoltage in the system. This fall or rise will be detected by the voltage relay and command will be given to disconnect the DG/MG from rest of the system according to the standards (Persson, 2007). As suggested by the standards disconnection time will be automatically adjusted. However if the load is almost equal to DG/MG generation, such relay cannot be expected to work, i.e. there will be small NDZ.

Frequency Relay:

Under the steady state condition of operation system frequency is always maintained at 1 p.u., but when suddenly loss of mains occurs then whole load has to supply by the DG/MG, load supplied may be larger or may be lesser than the DG/MG generation, which may cause the transient in frequency. Such change is detected by the frequency relay and command is given to disconnect the DG/MG from rest of the system according to the IEEE standards, shown in table 1. The disconnection will be performed according to the standards. However if the load is almost equal to DG/MG generation such relay cannot expected to work. Figure 3 shows the NDZ of frequency and voltage relay.

Table1: standards for voltage and frequency tolerance of DG (IEEE, 2008)

Voltage Range (% Nominal)	Max. Clearing Time (sec)	Frequency Range (Hz)	Max. Clearing Time (sec)
V < 50%	0.16	f > 60.5	0.16
50% ≤ V <88%	2.0	f< 57.0	0.16
V ≥ 120%	0.16	59.8 < f <57.0	Adjustable (0.16 to 300)

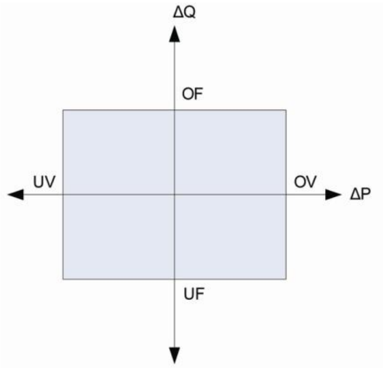

Figure 3: Non detection zone of UOV and UOF passive techniques(Marwa Ashour, 2013)

Rate of Change of Frequency (ROCOF) Relay:

This method is based on the local measurement of the generator voltage and estimation of the rate of change of frequency(Booth, 2011). The rate of change of frequency of the system will be measured continuously and is compared with a preset threshold rate of change of frequency to generate trip signal. Following an Islanding/LOM event, system's rate of change of frequency is directly proportional to the imbalance of amount of active power between the generator output and local load. Larger is the imbalance greater is the rate of change and faster the trip signal can be issued.

Simplified rotor swing equation in SI units:

$$J\frac{d\omega_r}{dt} = T_m - T_e \qquad \text{----(1)}$$

Where:
J – inertia constant [kg m2]
ωr – rotor speed [rad/sec]
Tm – mechanical torque [N m]
Te – electromagnetic torque [N m]

$$H = \frac{kinetic\ energy\ at\ synchronous\ speed}{machine\ nominal\ power} \qquad \text{----(2)}$$

$$= \frac{\frac{1}{2}J\omega^2{}_{ro}}{S_n}$$

Where;

H- inertia constants [s]

Taking into account that $\omega_r = 2\pi fr$ and $f_r = J/p$ initial rate of change of frequency during islanding can be calculated as follows (Booth, 2011):

$$J\frac{d\omega_r}{dt} = \Delta T$$

$$H = \frac{\frac{1}{2}J\omega^2{}_{ro}}{S_n}$$

$$ie.\ J = \frac{2HS_n}{\omega_{ro}{}^2}$$

Hence; $ROCOF = \frac{\Delta P \times f}{2 \times S_n \times H}$ ----(3)

Where,

ROCOF – Estimated rate of change of frequency [Hz/s]
ΔP – Change in active output power during Islanding/LOM event [MW]
S_n – Nominal generator rating [MVA]
f – Generator rated frequency [Hz]
H – Inertia constant of the generator [s]

The main theme in this ROCOF method is just the local measurement of the system operating frequency at the generator terminals. Figure 4, shows the block diagram of the method. It does not require any communication. Even though it has small NDZ, it generally provides a good sensitivity to genuine islanding.

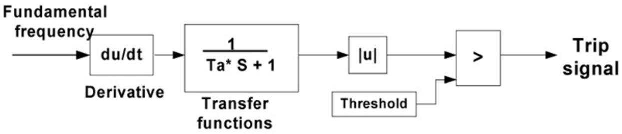

Figure 4: ROCOF relay block diagram (X. Ding, 2007)

Voltage Vector Shift (VVS) Relay:

The relay measures voltage phase changes in consecutive cycles (or half cycles) and compares the value with the preset threshold. Zero crossing technique is often used as method of angle measurement. Compared to other methods VVS is very fast. VVS is sensitive to network faults (both resulting in islanding situation and remote faults cleared by the utility). VVS is not sensitive to rate of change of frequency. Generator terminal voltage angle changes by θ due to step change in load current and the generator reactance, which is shown in figure 5. At the start of islanding situation, the cycle duration will either be shorter or longer, depending on if there is excess or a deficit of power in the islanded system (Walmir Freitas, 2005), so the detection of islanding can be done by detecting the change in cycle span.

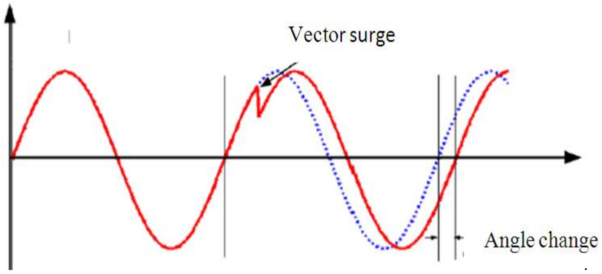

Figure 5: shift of vector during Islanding and detection algorithm(X. Ding, 2007)

Positive Sequence Impedance Relay:

The relay measures positive sequence voltage and positive current, with the help of these parameters positive sequence impedance is evaluated. As we know, positive and negative sequence measurements are the only reliable way to measure the impedance of a three-phase system. The algorithm compares the current instantaneous impedance to the instantaneous impedance from the previous 0.2 seconds. When the ratio changes suddenly trip signal can be issued by comparing it with threshold value (Dax Berven, 2009).

When loss of grid occurs then impedance change will occur. Under normal operation condition impedance is very small, where as it will change suddenly if the grid connection is failure. Sometimes with load switching also change of impedance occur however their range is smaller, so with proper setting of threshold value, islanding can be detected. Detail block diagram of the algorithm is shown in figure 6.

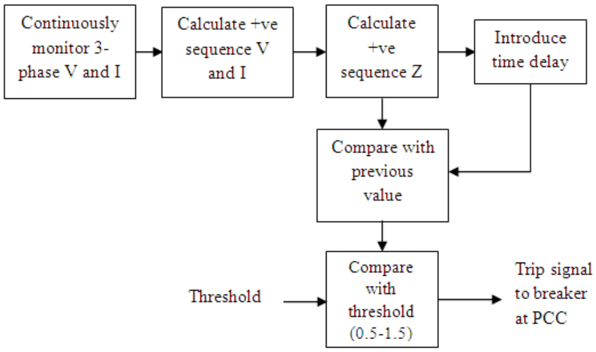

Figure 5: block diagram for Positive Sequence Impedance method

Selection of threshold is important because; small threshold might cause false tripping and larger threshold might cause no detection even during the islanding.

3. Test System

The test system consists of two 100KVA, 400V, DGs interconnected via 5 km long 11KV feeder, And Then the common system in connected to the grid via 11km long 11 KV line. The system consists of concentrated load on 11kv feeder, as well as on the DG networks and on the grid side. System is shown is figure 17. Any fault on the grid side or Loss of Mains because of any reason will be represented by opening the grid side breaker. Discussed methods will be tested whether they do detect Islanding/LOM or not. Any fault on the grid side or Loss of Mains because of any reason will be represented by opening the grid side breaker. Discussed methods will be tested whether they do detect Islanding/LOM or not. Test system computational model is shown in figure 7.

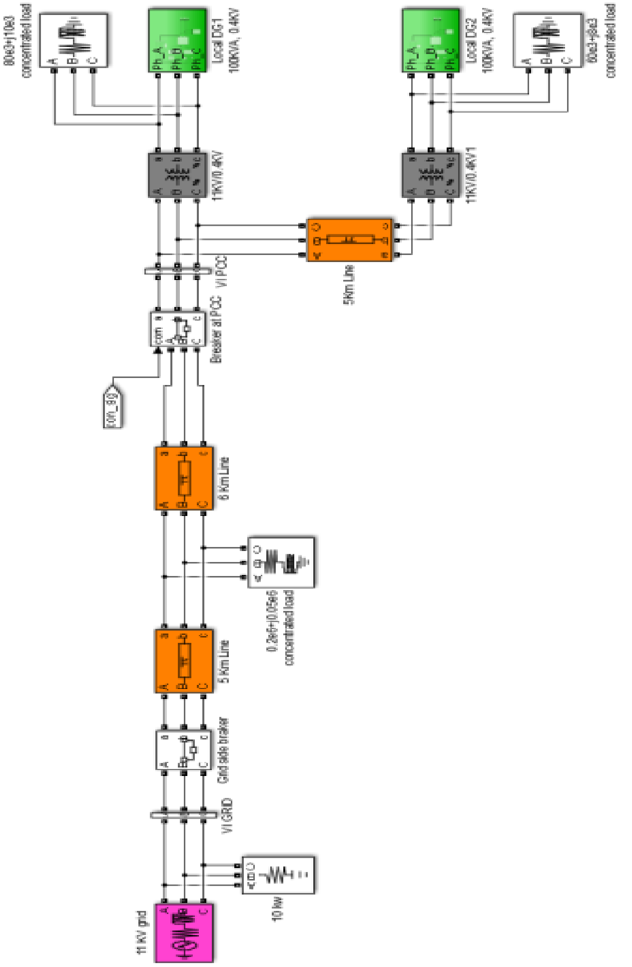

Figure 7: computational model of the layout

System has separate control block for detecting islanding/LOM and gives command to operate breaker at PCC. It also has data acquisition system for displaying all the variables.

4. Simulation Results and Discussion

At first entire load connected to the 11kV feeder are assumed to be on or it has peak load on the portion. Here, Peak load of the islanded portion is 200KVA+ 50KVAR. These simulations were run for 150 sec and at the mean time, i.e. at 30 sec grid is disconnected via grid side breaker, and the response of the system is observed. System is running at peak so it is expected that all methods should be able to detect islanding, because small capacity DGs cannot supply full load, and sudden transient in all variables will be observed. Times taken by different methods to detect islanding are noted and are presented in the table 2.

Table 2: various methods and time for LOM detection at peak load at islanded portion

SN	Method of Islanding detection	Detection Time (sec)
1	Current relay	0.17
2	Voltage relay	0.16
3	Frequency relay	0.43
4	Rate of change of frequency relay	0.27
5	Voltage vector shift relay	0.015
6	Positive Sequence Impedance relay	0.013

Similarly later the same circuit and control strategy was tested under the 50% of peak load at the islanded portion. Obtained results are presented in table 3.

Table 3: various methods and time for LOM detection for 50% of peak load at islanded portion

SN	Method of Islanding detection	Detection Time (sec)
1	Current relay	-
2	Voltage relay	0.16
3	Frequency relay	0.68
4	Rate of change of frequency relay	0.66
5	Voltage vector shift relay	0.015
6	Positive Sequence Impedance relay	0.005

Same test under the 10% over loading yield as shown in table 4;

Table 4: various methods and time for LOM detection for 10% of peak load at islanded portion

SN	Method of Islanding detection	Detection Time (sec)
1	Current relay	-
2	Voltage relay	-
3	Frequency relay	2.08
4	Rate of change of frequency relay	-
5	Voltage vector shift relay	0.015
6	Positive Sequence Impedance Relay	0.005

On decreasing the total load on the islanded portion time of detection found to increase. Similarly, after some threshold islanding will no more detected by most of the methods, however VVS and Positive Sequence Impedance methods are able to detect islanding. Samples frequency responses for detection and no detection of the islanding by frequency relay method is presented in figure 8, and figure 9.

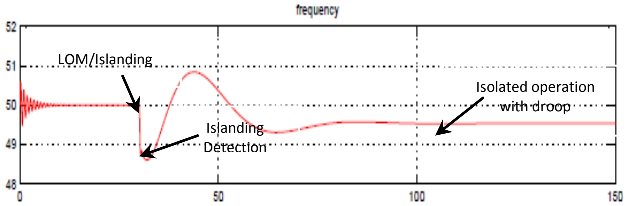

Figure 8: sample frequency response during LOM with larger imbalance of load and generation

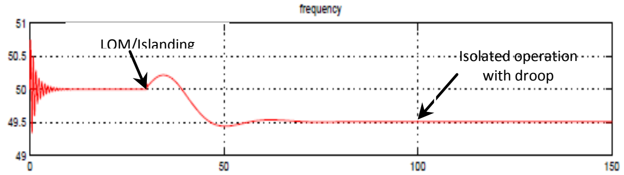

Figure 9: sample frequency response during LOM with load generation match

It is seem that VVS and Positive Sequence Impedance methods are able to detect islanding perfectly within very near range of load matching condition too. For confirmation they were further tested for the load switching inside the MG. In this test, Load of 17KW was switched on instantly and it is found that Voltage Vector Shift Relay made falls tripping. It means if the system have larger instantly switching loads then this method cannot give good result. However, the Positive Sequence Impedance Method did not make falls tripping. So, further test has been carried out to find its NDZ. In this step change in load was conducted in smaller step and the results obtained is presented in table 5;

Table 5: time of islanding detection by positive sequence impedance method at different loading

SN	% load on the islanded portion (% of peak load)	Detection Time (sec)
1	100%	0.013
2	80%	0.005
3	60%	0.005
4	40%	0.005
5	20%	0.005
6	0%	0.013

We can minimize the non detection zone area by decreasing threshold, but there will be larger chance of false tripping; knowing that good islanding detection should discriminate between real islanding and other switching actions, reducing threshold in not a good approach.

5. Conclusion and Future Work

It is found that passive methods of islanding/ LOM detection techniques have range of non detection zone even though they are suitable for larger imbalance. VVS and Positive Sequence Impedance Method are better than other methods; among them also VVS suffers from falls tripping. Hence, in context to Nepal where mainly DGs/MGs are far apart from the grid, and also DGs (i.e. micro hydro) are at distances themselves, Positive Sequence Impedance Method is appropriate among various passive methods reviewed.

Future of electric distribution system will be dominated by distributed energy resources; with complex active distribution network, detection of islanding and protection against it will be very important. Most importantly, designed protection system should be capable of detecting all the islanding condition but should not cause false trip, so, as next step of research active methods and hybrid methods will be tested and examined and a best method will be developed.

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