Islanding and Detection of Distributed Generation Islanding using Negative Sequence Component of Current

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Abstract - **There is a renewed interest in the distributed generation (DG) mainly due to the environmental concern and electricity market liberalization. Many utilities around the world already have a significant penetration of DG in their systems. But there are many issues to be resolved before DG becomes an integral part of the utilities around the world. One of the main issues with DG is islanding. Islanding occurs when a portion of the distribution system becomes electrically isolated from the remainder of power system yet continues to be energized by distributed generators. An important requirement to interconnect a DG to the power distributed system is the capability of the DG to detect islanding. Failure to trip islanded generators can lead to a number of problems to the generators and the connected loads. The current industry practice is to disconnect all distributed generators immediately after the occurrence of islands. Typically, a distributed generator should be disconnected within 100 to 300 ms after the loss of the main supply. To achieve such a goal, this paper proposes that each distributed generator must be equipped with an islanding detection device using a negative sequence component of the current.**

Keywords— Islanding, islanding detection, distributed generation, sequence components

I. INTRODUCTION

Distributed generations have been broadly used and are expected to be an important element in the future electric power systems [1]. These generation systems have characteristics which are different from those of conventional large capacity fossil and nuclear generation systems. Distributed generations are relatively small and many of them make use of renewable energy such as a wind power or a hydraulic power. And, when the distributed generation systems are operated in parallel with utility power systems, especially with reverse power flow, the power quality problems become significant. Power quality problems include frequency deviation, voltage fluctuation, harmonics and reliability of the power system. In addition, most important problem is an islanding protection.

When a distributed generation system with some loads is disconnected from the utility power system, the distributed generation is going to supply the loads and, although this is rare, continue an islanded operation of power system. The islanded operation should be avoided because of safety reasons for maintenance man and power quality reasons of distributed lines. To solve these problems, islanding detectors are used to detect an islanded operation and trip the circuit breaker between the power system and the distributed generation [2],[3].

II. ISLANDING AND ISLADING DETECTION TECHNIQUES

A. *What is an islanding?*

A fault occurring in the power distribution system is generally cleared by the protective relay that is located closest to the faulty spot (B1 opens). As a result, a distributed generation tries to supply its power to part of the distribution system that has been separated from the utility's power system.

In most cases, this distributed generation assumes an overloaded condition, where its voltage and frequency are lowered and it is finally led to stoppage. However, though this is a rare case, a generator (or a group of generators) connected to this islanded system is provided with a capacity that is large enough to feed power to all the loads accommodated in the islanded system. When the loads are fed power only from the distributed generations even after the power supply is suspended from the power company, such a situation is called an "islanded operation" or "islanding".

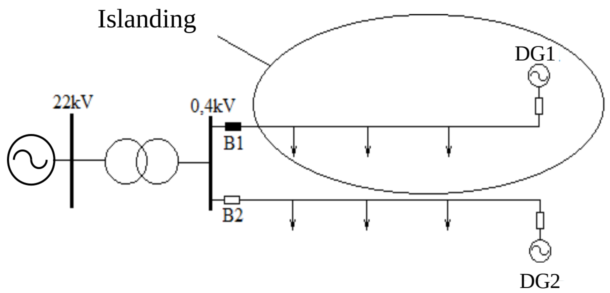

Figure 1. A part of the grid is islanded when the B1 opens

If a condition of islanded operation is continued, there can be concern about physical injury because of the inspection and restoration personnel or the public coming in contact with the live parts. In addition, when the power is supplied from the distributed generations, the quality of the fed power may be lowered as compared with the cases when the power is fed from the power company. It is often considered that the lowered quality may affect the loads adversely. At the power company, programs have been established so that the relevant circuit breaker or a switch is automatically closed at the substation after the lapse of the predetermined time period, in order to achieve prompt restoration from a service interruption. However, if the above-mentioned islanded operation is continued longer, a condition of asynchronous closure is assumed and the fault may be evolved further. This results in a further delay in the restoration from the failure. For

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the reasons described above, the distributed generations and the protective devices applied to the connecting point of their system are required to trip the circuit breaker located at this connecting point, by sensing such a condition when the power supply from the system is lost. This function is referred to as the "islanding detection" or "loss-of-mains protection."

B. Islanding detection techniques

Islanding detection techniques can be divided into remote and local techniques and local techniques can further be divided into passive, active techniques as shown in Figure 2.

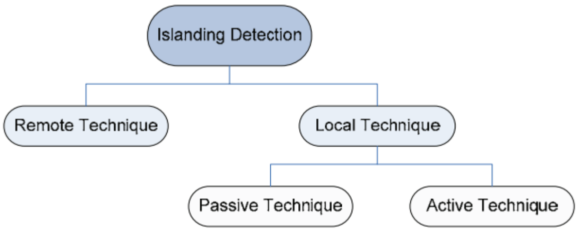

Figure 2. Islanding detection techniques

Table 1. Summarize the islanding detection techniques, their advantage and disadvantage, and examples [4].

Islanding Detection Techniques	Advantages	Disadvantages	Examples
1. Remote Techniques	• Highly reliable	• Expensive to implement especially for small systems.	• Transfer trip scheme • Power line signaling scheme
2. Local Techniques			
a. Passive Techniques	• Short detection time • Do not perturb the system • Accurate when there is a large mismatch in generation and demand in the islanded system.	• Difficult to detect islanding when the load and generation in the islanded system closely match • Special care has to be taken while setting the thresholds • If the setting is too aggressive then it could result in nuisance tripping	• Rate of change of output power scheme • Rate of change of frequency scheme • Rate of change of frequency over power scheme • Change of impedance scheme • Voltage unbalance Scheme • Harmonic distortion scheme
b. Active techniques	• Can detect islanding even in a perfect match between generation and demand in the islanded system.	• Introduce perturbation in the system • Detection time is slow as a result of extra time needed to see the system response for perturbation • Perturbation often degrades the power quantity and if significant enough, it may degrade the system stability even when connected to the grid	• Reactive power export error detection scheme • Impedance measurement Scheme • Phase (or frequency) shift schemes

C. *Proposed islanding detection method*

Integrations of Distributed Generations (DGs) in the distribution network are expected to play an increasingly important role in the electric power system infrastructure and market. As more DG systems become part of the power grid, there is an increased safety hazard for personnel and an increased risk of damage to the power system. Despite the favorable aspect grid-connected DGs can provide to the distribution system, a critical demanding concern is islanding detection and prevention.

Failure to trip islanded DG can lead to a number of problems for these resources and the connected loads, which includes power quality, safety and operation problems. Therefore, the current industry practice is to disconnect all DGs immediately after the occurrence of islands. The disconnection is normally performed by a special protection scheme called islanding detection relays which can be implemented using different techniques.

Recently pattern recognition technique based on Wavelet Transform [5-7] has been found to be an effective tool in monitoring and analyzing power system disturbances including power quality assessment and system protection against faults. This paper investigates the time-localization property of Wavelet transform for islanding detection by processing negative sequence components of current signals retrieved at the target DG location. As negative sequence components provide vital information in case of unbalanced conditions in power system, thus the same has been considered for the proposed islanding detection technique which is subjected to disturbance during islanding process such as deviations in frequency, voltage, current and active power etc.

As shown in figure 3, phase voltage of the DG to change an instant way [8]. This change happened on the voltage waveform at different times for each phase. With regard to the unbalance between these phases of the voltage as figure 3, the negative sequence component of current will exist during islanding. Inverse order components of the current signal are separated from the current in the location of DG connection on.

The method of detecting the fault suitable isolation is to compare the value negative sequence component of current value is defaulted. A method based on negative sequence component of current combined with a damping characteristic of this component has the ability to distinguish

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the condition happens the islanding with the other operators in the case of the grid even when the problem is not symmetric.

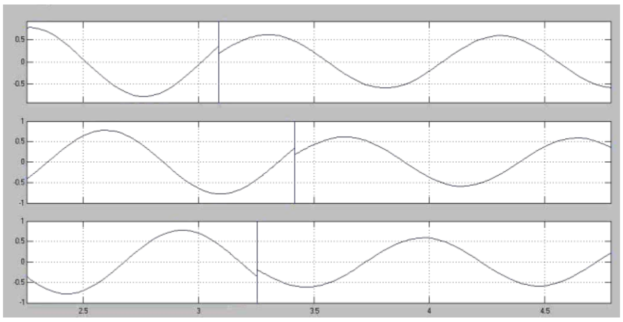

Figure 3. Three-Phases voltage signal under Islanding Condition retrieved at the target DG location

III. SIMULATION MODEL

In order to investigate the performance of the different techniques during various contingencies a simulation model was implemented. It is important that the model reflects a real system in all vital parts. The behavior of the simulated system must be similar to what happens in a real situation. How this has been achieved is described in the following.

The grid is presented in figure 4 include 110 kV power transmission system and 50 Hz short circuit capacity of 100 MVA is illustrated by a voltage source and resistor. Grid system is connected to a distribution system through a transformer 110/22 kV. DG1 and DG2 is scattered sources, each source including 3 generator has a capacity of 1.5 MW. Capacitors have a capacity of 3 MVAr. Load 1: PD1 = 6 MW, QD1 = 2,5 MVAr. Load 2: PD2 = 3 MW, QD2 = 1 MVAr. Load3: PD3= 9 MW, QD3= 4,5 MVAr.

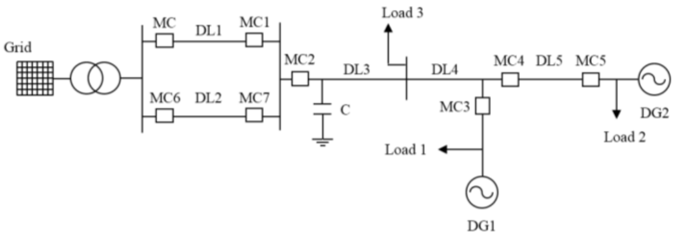

Figure 4. The studied Power Distribution network with multiple DGs

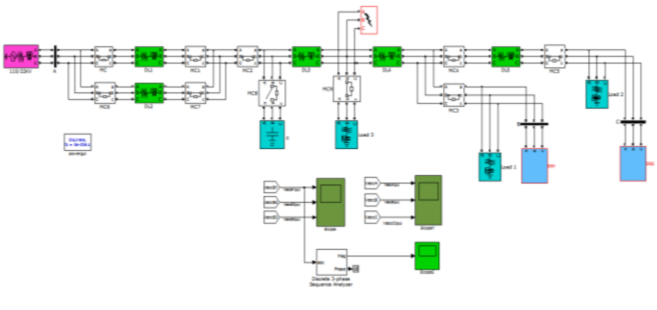

Figure 5. MATLAB/SIMULINK MODEL

To distinguish the islanding condition with the other conditions, we analyze the case of the following operators:

+ Disconnect/connect a circuit of parallel lines
+ Disconnect the DG with the distribution grid, this case is islanding operation
+ Disconnect/connect DGs to the grid
+ Change the load in power system
+ Disconnect/connect the capacitor
+ Asymmetric load
+ Short circuit asymmetry

Simulation results

1. Disconnect/connect a circuit of parallel lines

Suppose that at the time of 0.5 s we trip a circuit of parallel lines (DL1) out of the system by opening the breaker MC1. Figure 6 shows that at the time of 0.5 s the value negative sequence component of current begins to rise and its characteristic off gradually over time. Continue measuring the value negative sequence component of current at the moment that way current components reaches the maximum value after 0.1 s (5 cycles) and then get this value.

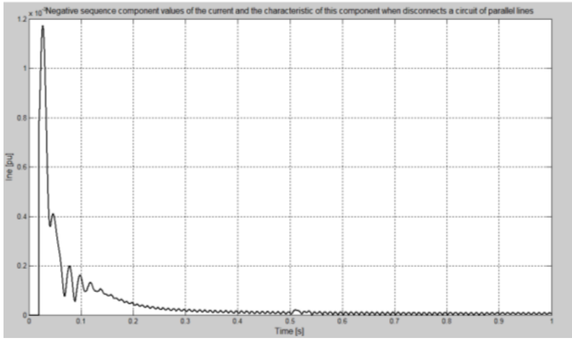

Figure 6. Negative sequence component values of the current and the characteristic of this component when disconnects a circuit of parallel lines

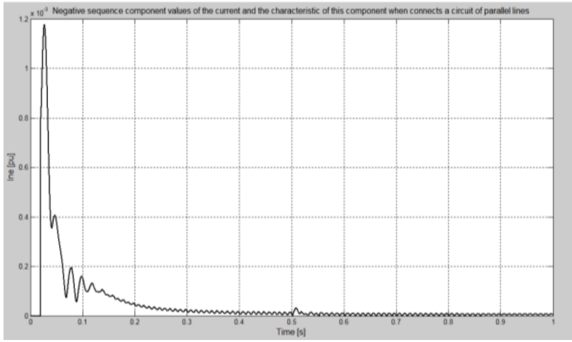

Figure 7. Negative sequence component values of the current and the characteristic of this component when connects a circuit of parallel lines

2. Disconnect the DG with the distribution grid. This is the islanding condition.

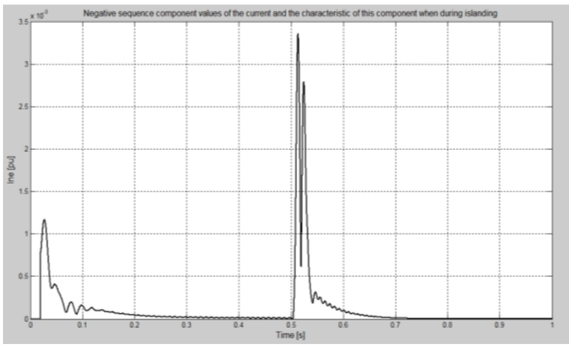

Figure 8. Negative sequence component values of the current and the characteristic of this component when during islanding

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3. Disconnect/connect DGs to the grid

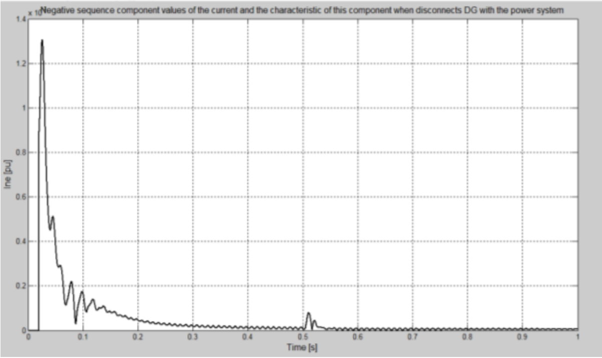

Figure 9. Negative sequence component values of the current and the characteristic of this component when disconnects DG with the power system

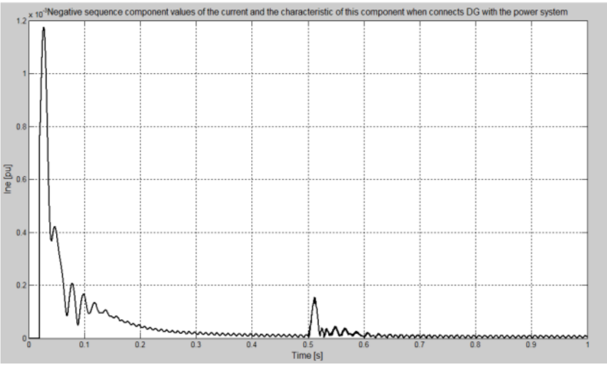

Figure 10. Negative sequence component values of the current and the characteristic of this component when connects DG with the power system

4. Change the load in power system. This is the sudden load change condition. Where suddenly load is changed up to 50%.

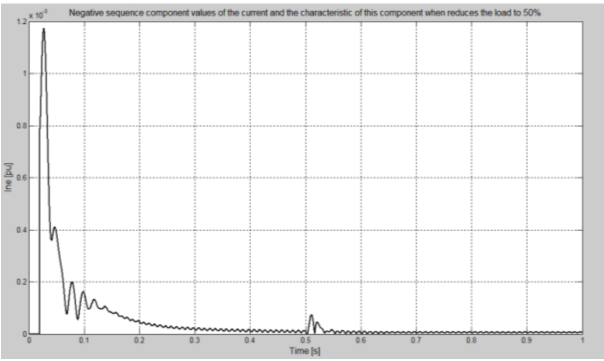

Figure 11. Negative sequence component values of the current and the characteristic of this component when reduces the load to 50%

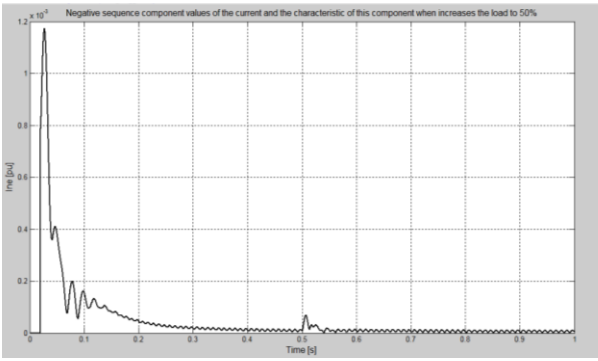

Figure 12. Negative sequence component values of the current and the characteristic of this component when increases the load to 50%

5. Disconnect/connect the capacitor

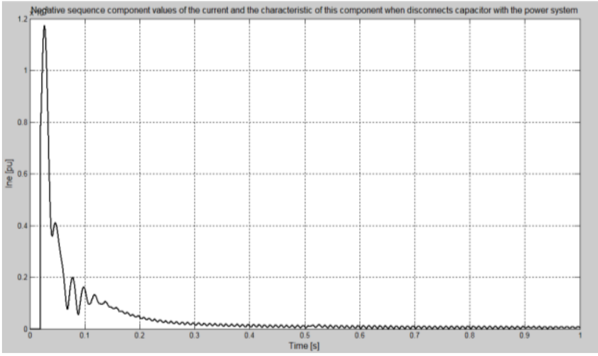

Figure 13. Negative sequence component values of the current and the characteristic of this component when disconnects capacitor with the power system

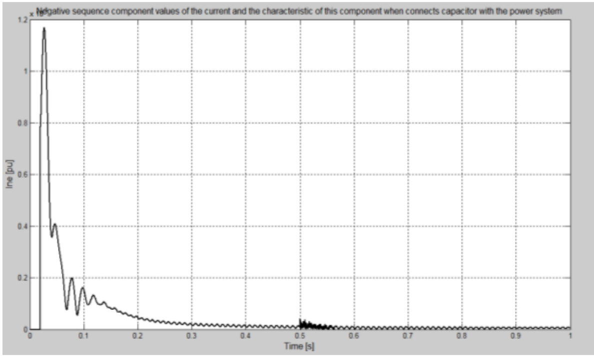

Figure 14. Negative sequence component values of the current and the characteristic of this component when connects capacitor with the power system

6. Asymmetric load

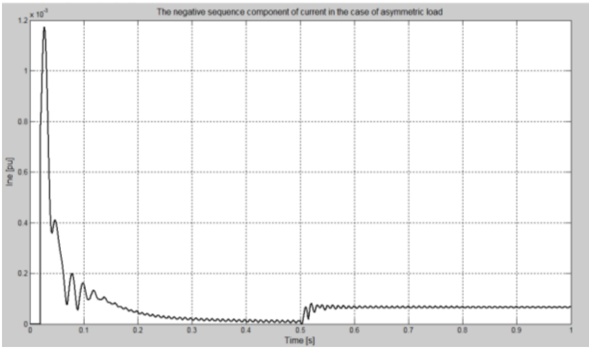

Figure 15. Negative sequence component values of the current and the characteristic of this component when the load is asymmetrical

7. Short circuit asymmetry

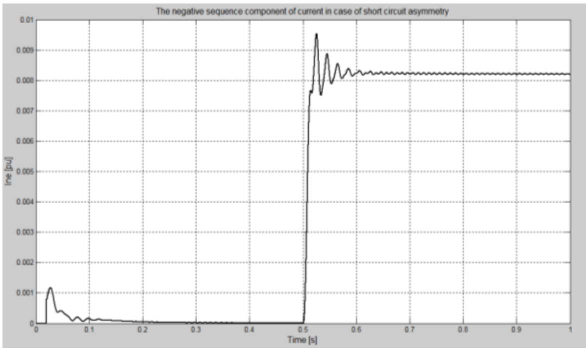

Figure 16. Negative sequence component values of the current and the characteristic of this component when the system occurs short circuit asymmetry

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From the assumed the operation of the above condition, we have the general simulation results as table 2.

Table 2: General table the results measured after simulations

The cases of operation		The maximum value of negative sequence component of the current(pu)	The value negative sequence component of current at the moment that way current components reaches the maximum value after 0.1 s (5 cycles) (pu)
Disconnect/connect a circuit of parallel lines	Disconnect a circuit of parallel lines	0.0012	9.7110e-005
	Connect a circuit of parallel lines	0.0012	9.7843e-005
Disconnect/connect DGs to the grid	Disconnect DG2 with the power system	0.0013	9.0816e-005
	Connect DG2 with the power system	0.0012	9.5656e-005
Change the load in power system	Reduces the load to 50%	0.0012	9.7110e-005
	Increases the load to 50%	0.0012	9.7110e-005
Disconnect/connect the capacitor to the grid	Disconnect the capacitor to the grid	0.0012	9.7110e-005
	Connect the capacitor to the grid	0.0012	9.7264e-005
Asymmetric load		0.0012	9.7110e-005
The maximum value		0.0013	9.7843e-005
Islanding condition	Disconnect the DG with the distribution grid	0.0034	6.7996e-005
Short circuit asymmetry		0.0095	0.0083

From table 2, we see that the maximum value of negative sequence component of current is 0.0013 pu and the value of negative sequence component of current at the moment that way current components reaches the maximum value after 0.1 s (5 cycles) is 9.7843e-005 pu (except the islanding operation case and the short circuit asymmetry case).

For the case of asymmetric short circuit, the value of negative sequence component of current is largest. This value is almost not reduced after 0.1 seconds since the power system occurs the asymmetric short circuit and the overcurrent protection relay will recognize this fault case. Therefore, to distinguish the islanding operation case with the case of asymmetric short circuit and these cases of another operation that has been in the simulation, we give the value threshold to detect the islanding condition as follows:

$$0.0013\text{pu} < I_{2set} \leq 0.0034\text{pu}$$

IV. CONCLUSION

Based on the measurement of electrical parameters of generator position, the article has presented a method using the negative sequence component of current combined with a damping characteristic of this component to detect the islanding condition. The negative sequence component of current is separated from the current signal in distributed generations. This method was simulated with the different operating conditions above.

An islanding detection method using a negative sequence component of current combined with a damping characteristic of this component can detect the islanding condition exact and doesn't operate wrong when occurs the disturbance in power system.

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