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Detection of Distributed Generation Islanding Using Negative Sequence Component of Voltage

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Abstract

Distributed generation in simple term can be defined as a small-scale generation. It is an active power generating unit that is connected at distribution level [1]. IEEE defines the generation of electricity by facilities sufficiently smaller than central plants, usually 10 MW or less, so as to allow interconnection at nearly any point in the power system, as Distributed Resources [1]. The advancement in new technology like fuel cell, wind turbine, photo voltaic and new innovation in power electronics, customer demands for better power quality and reliability are forcing the power industry to shift for distributed generations. Hence distributed generation (DG) has recently gained a lot of momentum in the power industry due to market deregulations and environmental concerns. Islanding occurs when a portion of the distribution system becomes electrically isolated from the remainder of the 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 detection. 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 voltage.

Introduction

The main philosophy of detecting an islanding situation is to monitor the DG output parameters and system parameters and decide whether or not an islanding situation has occurred from changes in these parameters. 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 1.

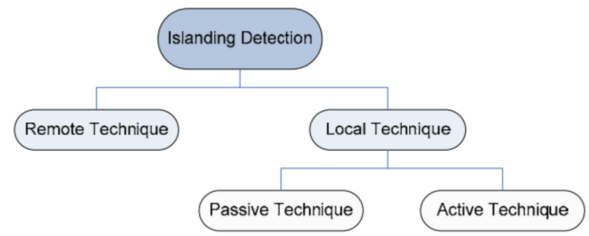

Figure 1. Islanding detection techniques

Table 1. Summarize the islanding detection techniques, their advantage and disadvantage, and examples [2].

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

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.

Islanding operation is a condition that occurs when a part of a network is disconnected from the remainder of power system but remains energized by DG units interconnected to the distribution system, which normally comprises multiple DGs with diverse technologies. 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 [3-5] 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 voltage and 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 and active power etc.

As shown in figure 2, phase voltage of the DG to change an instant way [6]. This change happened on the voltage waveform at different times for each phase. With regard to the unbalance between the phase of the voltage as figure 2, the negative sequence component of voltage will exist during islanding. Inverse order components of the voltage signal are separated from the voltage in the location of DG connection on.

The method of detecting the fault suitable isolation is to compare the value negative sequence component of voltage value is defaulted. A method based on negative sequence component of voltage combined with a damping characteristic of this component has the ability to distinguish the condition happens the islanding with the other operators in the case of the grid even when the problem is not symmetric.

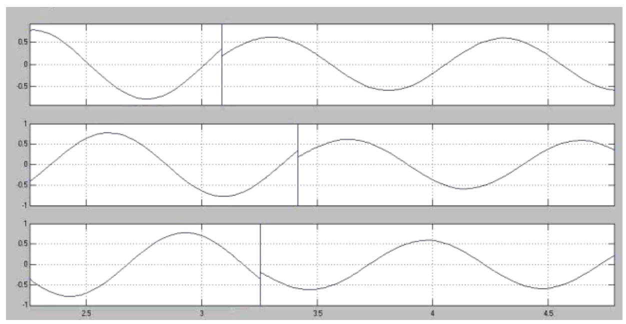

Figure 2. Three-Phase voltage signal under Islanding Condition retrieved at the target DG location

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 3 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 1.5 MVAr. Load 1: PD1 = 5 MW, QD1 = 2 MVAr. Load 2: PD2 = 2 MW, QD2 = 0.5 MVAr. Load3: PD3= 8 MW, QD3= 4 MVAr.

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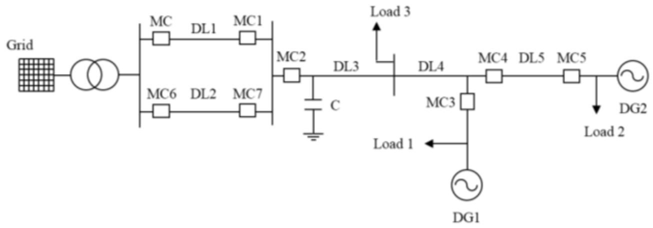

Figure 3. The studied Power Distribution network with multiple DGs

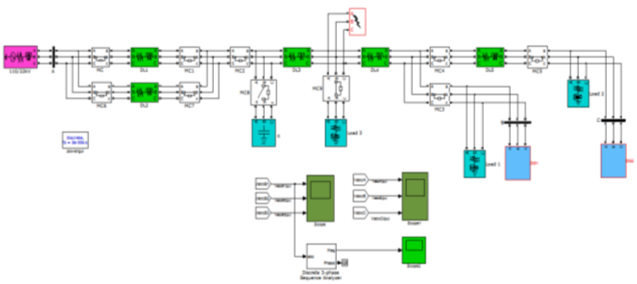

Figure 4. MATLAB/SIMULINK MODEL

The negative sequence component of voltage value appears in the short circuit incident status not symmetrical or asymmetrical loads in power system. The method of detecting the correct islanding condition if it can distinguish when it happens the islanding condition with the other operating status including when short circuit occurs.

Short circuit case asymmetry and asymmetry load:

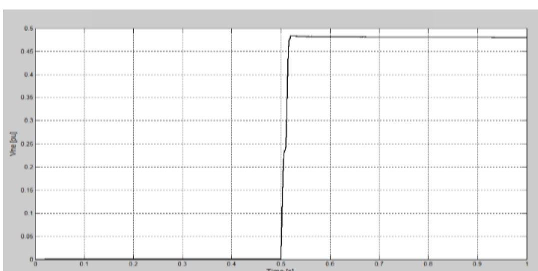

Figure 5. The negative sequence component of voltage in case of short circuit asymmetry

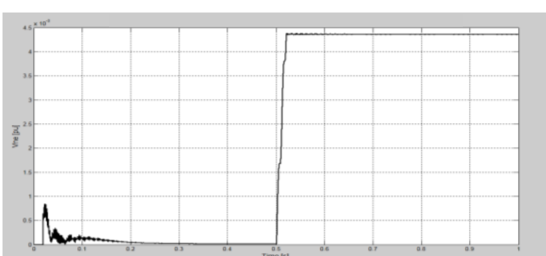

Figure 6. The negative sequence component of voltage in the case of asymmetric load

From figure 5 and 6, we see that the negative sequence component of voltage increases at the time of the fault (t = 0.5 s) but then not reduce but also increased after the transition period.

To distinguish the islanding condition with the other condition, 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

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 machine trip MC1. Figure 7 shows that at the time of 0.5 s the value negative sequence component of voltage begins to rise, reaching maximum values is 0.0140 pu and its characteristic off gradually over time. Continue measuring the value negative sequence component of voltage at the moment that way voltage components reaches the maximum value after 0.1 s (5 cycles) and then get the resulting 2.4166 x 10^{-4} pu.

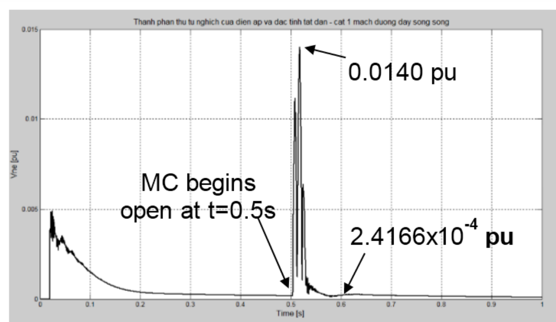

Figure 7. Negative sequence component values of the voltage and the properties of this component off when disconnects a circuit of parallel lines

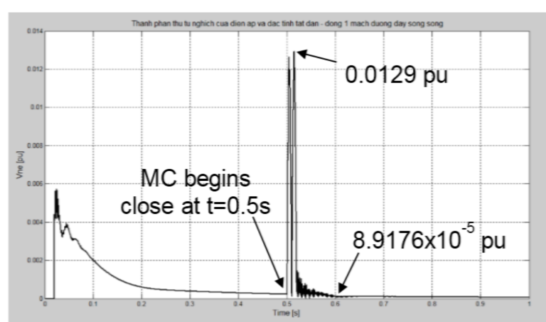

Figure 8. Negative sequence component values of the voltage and the properties of this component off when connects a circuit of parallel lines

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

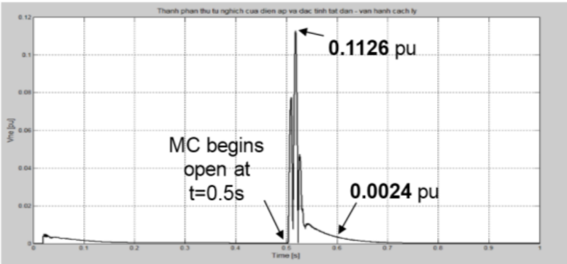

Figure 9. Negative sequence component values of the voltage and the properties of this component off when during islanding

3. Disconnect/connect DGs to the grid

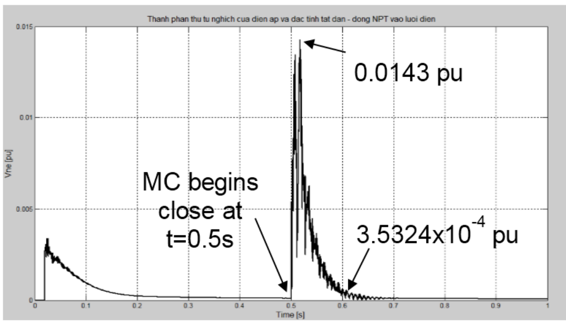

Figure 10. Negative sequence component values of the voltage and the properties of this component off when connects DG with the power system

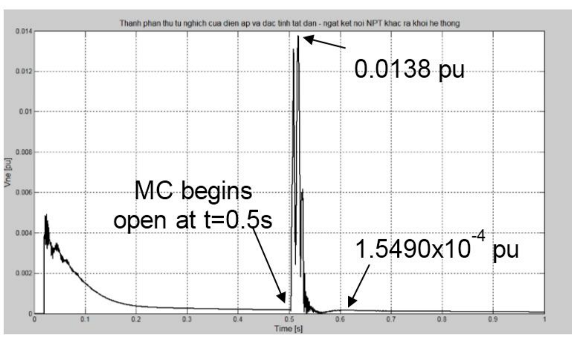

Figure 11. Negative sequence component values of the voltage and the properties of this component off when disconnects DG with the power system

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

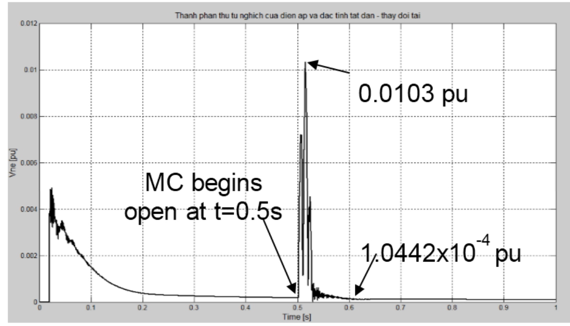

Figure 12. Negative sequence component values of the voltage and the properties of this component off when reduces the load to 50%

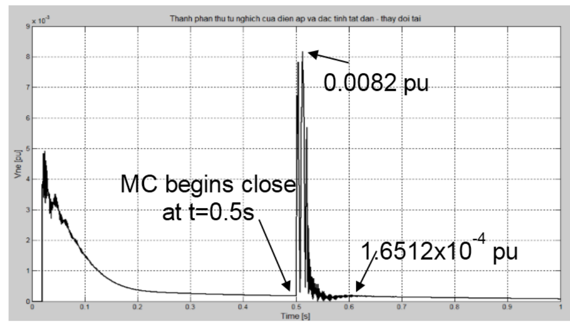

Figure 13. Negative sequence component values of the voltage and the properties of this component off when increases the load to 50%

5. Disconnect/connect the capacitor

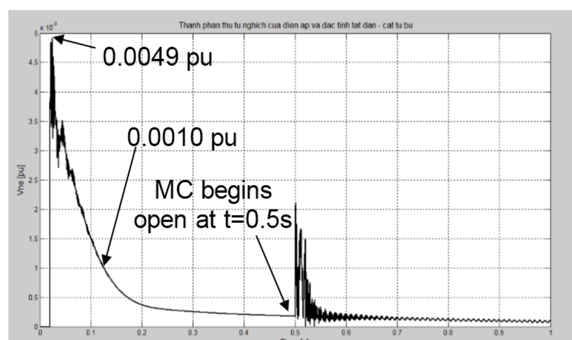

Figure 14. Negative sequence component values of the voltage and the properties of this component off when disconnects capacitor with the power system

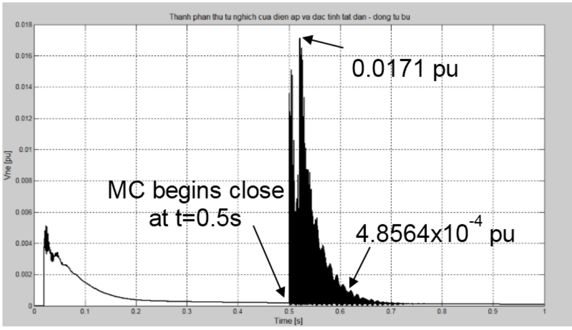

Figure 15. Negative sequence component values of the voltage and the properties of this component off when connects capacitor with the power system

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 voltage (pu)	The value negative sequence component of voltage at the moment that way voltage 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	0.0140	2.4166×10^{-4}
	Connect a circuit of parallel lines	0.0129	8.9176×10^{-5}
Disconnect/connect DGs to the grid	Connect DG2 with the power system	0.0138	1.5490×10^{-4}
	Disconnect DG2 with the power system	0.0143	3.5324×10^{-4}
Change the load in power system	Increases the load to 50%	0.0082	1.6512×10^{-4}
	Reduces the load to 50%	0.0103	1.0442×10^{-4}
Disconnect/connect the capacitor to the grid	Disconnect the capacitor to the grid	0.0049	0.0010
	Connect the capacitor to the grid	0.0171	4.8564×10^{-4}
The maximum value		**0.0171**	**0.0010**
Islanding condition	Disconnect the DG with the distribution grid	**0.1126**	**0.0024**

From table 2, we see that the maximum value of negative sequence component of voltage is 0.0171 pu and the value of negative sequence component of voltage at the moment that way voltage components reaches the maximum value after 0.1 s (5 cycles) is 0.0010 pu (except the islanding operation case). Compare this value with the islanding operation case, we give the value threshold to detect the islanding condition:

$$\mathbf{0.0171pu < V_{2set} < 0.1126pu}$$

Conclusion

An islanding detection method using a negative sequence component of voltage 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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