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An Approach to Detect Islanding in Distributed Generation System

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Abstract: ***One of critical concerns in the operation of grid connected distributed generating units is the occurrence of islanding. The islanding protection for distributed generators (DGs) becomes an important and emerging issue in power system protection since the distributed generator installations are rapidly increasing and most of the installed systems are interconnected with distribution network. Anti-islanding methods are divided into passive and active methods. The passive methods are based on measurement of the natural effects of islanding. The active methods use the effects by intentional transients or harmonics. An islanding detection method based on impedance measurement at the point of common coupling is proposed here. It is found that, on islanding the variation in impedance is considerably higher than that of grid connected DGs and this variation is enough to indentify the islanding condition. In addition, this method is highly robust to different grid disturbances and stiffness and effective for multiple DGs running in parallel.***

Keywords: Distributed generation, interconnected system, Islanding detection, Remote techniques

1. Introduction

Recently, because of hazardous impact on environment and exhaustion of fossil fuel, distributed generation (DG) units based on renewable energy source (solar photovoltaic, micro-hydro, wind power and landfill gas etc.) has become one of the main issues. Distributed generators (DG) are also contributing to improve power quality, minimizing peak loads as well as decreasing the need for reserve margin along with high efficiency operation and safety. An islanding in DGs refers to the condition when the DGs and local loads are disconnected from the grid and DGs keep supplying the power into the local loads [1][2]. Most of DGs may be connected in parallel and supply power into power grids as well as local loads. Therefore, DG must be operated in such an inherently safe manner that DG should supply the power to the network loads only if the grid supply is available [3]. Islanding operation of the DGs has many negative impacts on utility power system and the DG itself like low power-quality, interference to grid-protecting devices, equipment damage, and even personnel safety hazards. Therefore on islanding, the connected DG must detect the loss of utility supply and disconnect itself from power grid as soon as possible. This paper deals with a particular problem that occurs at the interface between a distributed generation plant and the rest of the power system. The problem can be described as islanding detection in power systems. The problem has been investigated and discussed extensively in the last few years [5][6].

Recent trend of installation of distributed generator at low voltage busses at consumers end has created some new challenges for protection engineers that are different from traditional radically based protection methodologies

1.1 Existing Islanding Detection Techniques

Islanding detection techniques can be divided into remote and local techniques and local techniques can further be divided into passive, active and hybrid techniques as shown in Figure 1[6].

Remote islanding detection techniques are based on communication between grid and DGs. Although these techniques may have better reliability than local techniques, they are expensive to implement and hence uneconomical [1] [2] .Some of the remote islanding detection techniques are as follows [6]:

- Power Line Signaling Scheme
- Transfer Trip Scheme

Local detection Techniques are based on the measurement of system parameters at the DG site, like voltage, frequency, etc [3]. It is further classified as

- Passive Detection Techniques
- Active Detection Techniques
- Hybrid Detection Techniques

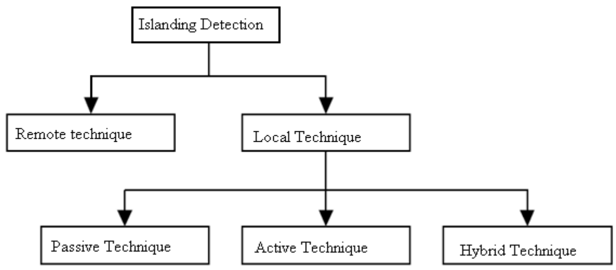

Figure1: Islanding detection techniques

1.1.1. Passive Detection Technique

Passive detection technique is that technique which uses the grid parameters and measurements (voltage, frequency, harmonic content, etc.) in order to detect islanding operation. The boundary limits of these parameters define the non detection zone (NDZ). If the local loads have similar power capacity of the DG system, i.e., all the generated power is consumed locally, then voltage and current levels at the point of common coupling (PCC) will only vary slightly when islanding occurs.[1][4] The system variables will be then within the boundary limits and the islanding condition will remain undetected. Passive methods have, therefore, a large NDZ. This technique is conceptually simple and easy to implement and do not introduces any change to the power quality of the system.[6]

1.1.2. Active Detection Technique

Active detection technique directly interacts with the power system operation by introducing perturbations. In this technique, a perturbation is injected in the current waveform to drive one of the system parameters out of its limits during islanding operation [1][2]The idea of this technique, is that a small perturbation will result in a significant change in system parameters when the DG is islanded, whereas the change will be negligible when the DG is connected to the grid. In order to reduce the NDZ, particularly in cases where the local loads are close in capacity to the DG system active detection technique has been proposed. [7]

1.1.3. Hybrid Detection Technique

Hybrid detection technique employs both the active and passive detection techniques. The active technique is implemented only when the islanding is suspected by the passive technique [8][9].

2. Detection of Islanding by Impedance Measurement

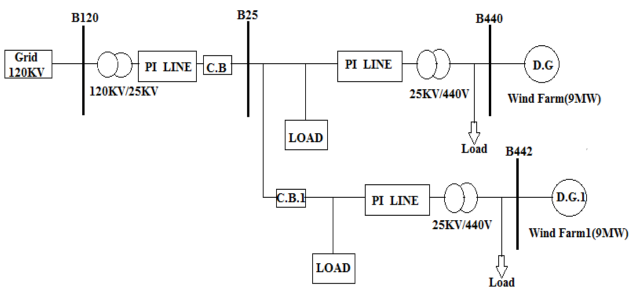

Figure 2: Distribution system connected with DG

2.1 Description of the model

The model shown in figure. 2 is having two wind farms named DG and DG1, each of 9MW connected in parallel using detailed model of doubly-Fed Induction generators (DFIG) driven by a wind turbine. Each wind farm consists of six wind turbines of 1.5 MW connected to a 120 KV grid through a 25 KV feeders. On both generation buses a resistive load and a load consisting of a motor load (1.68 MW induction motor at 0.93 PF) and a resistive load is connected on the same feeder at bus B25. Wind turbine is using a double fed induction generator (DFIG) and an AC/DC/AC IGBT based force commuted converter.

The stator winding of both DFIG is connected directly to the 50 Hz grid and the rotor fed at variable frequency through AC/DC/AC converter. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing the mechanical stress on the turbine during gusts of wind. The optimum turbine speed producing maximum mechanical energy for a given wind speed .The wind speed is initially at speed of 8m/s and then increased to 14m/s by providing step time of 5second.

In this model a resistive load of 500KW and a load consisting of a motor load and of a 200-kW resistive load are separately connected to both the parallel feeder connected to wind farms, and these parallely connected wind farms are connected to 120 grid. Wind turbines use a doubly-fed induction generator (DFIG) consisting of a wound rotor induction generator and an AC/DC/AC IGBT-based converter. The stator winding is connected directly to the 50 Hz grid while the rotor is fed at variable frequency through the AC/DC/AC converter. The voltage generated by each DFIG of 440 volt is stepped up to voltage level of 25KV by transformer connected across each wind farm side, this stepped up 25 KV voltage is transmitted by transmission line and then stepped up to grid level of 120KV. In between this transmission a fault block is connected to connect impedance measurement block therefore impedance can be measured by this impedance measurement block. Impedance is measured for different switching condition of circuit breaker of CB1 which leads to identify islanding and non islanding condition for DG1. The voltage and current signals are retrieved at the target DG location for islanding conditions and non-islanding conditions. The possible situations of islanding and non-islanding conditions studied are given as follows:

Condition-1: Both the three phase circuit breaker & three phase circuit breaker1 are in closed conditions. That is the normal condition.

Condition-2: This is the sudden load change condition in which load is suddenly increased and decreased up to a certain level. This is also normal condition as both the DGs are connected to system.

Condition-3: Three phase circuit breaker is permanently closed. Three phase circuit breaker 1 is opened. As after switching off the three phase breaker 1 whole part DG 1 is isolated from the remaining part of the power system. So this is the islanding condition for DG 1.

Above conditions are simulated under possible variations in operating loading at normal, minimum and maximum loading conditions. The loads are varied at the DG end. The voltage and current signals are retrieved at the target DG location. The complete simulation is carried out using MATLAB-SIMULINK software package.

The details of the generator, DGs, transformers, distribution lines and loads are mentioned as below:

- Both Distributed Generators (DG): Wind farm (9 MW) consisting of six 1.5-MW wind turbines (Doubly Fed Induction Generator) is connected to a 25-kV distribution system exports power to a 120-kV grid through a 30-km 25-kV feeder.
- Turbine data: Nominal wind turbine mechanical output power = 9MW, Wind Speed 14m/s,
- Generator data: Nominal power 9MW, generated voltage 440V, Stator resistance = 0.00706pu, Stator leakage inductance = 0.717pu, Rotor resistance= 0.0056pu, Rotor

leakage inductance = 0.156pu, Magnetizing inductance = 2.9pu.

- Transformer T1: Rated MVA = 47, winding 1 rated kV = 120, winding 2 rated kV = 25.
- Transformer T2: Rated MVA = 2, winding 1 rated kV = 25, winding 1 rated kV = 0.575.

3. Results

The islanding detection method described in this paper is implemented in Matlab & Simulink software for grid connected to distributed generator supplying the load The comparison between islanding and non-islanding conditions (normal operation) is carried out and experimental results obtained are as follows:

3.1. Normal Condition Results

Initially, in wind speed block wind speed is set at 8 m/s, so in the result wind speed graph is starts from 8 m/s, then as the step time of 5 is set therefore after 5 second at t = 5s, wind speed increases to 14 m/s. As after 5 second (at t = 5 s) wind speed increase from initial value, the generator starts generating active power and the generated active power starts increasing smoothly (together with the turbine speed) to reach its rated value of 9 MW in approximately 15 seconds. Over that time frame the turbine speed also increased from 0.7 pu to 1.21 pu to follow the tracking characteristics. And the pitch angle of the turbine blades is initially at zero degree, as DFIG reaches to its rated output power of 9MW, pitch angle is increased (in order to limit the mechanical power). At nominal power, the DFIG absorbs reactive power (required for excitation of DFIG), so in the result it drops slightly.

All results are shown separately for normal (non islanding) condition.

Initially, in wind speed block wind speed is set at 8 m/s, so in the result wind speed graph ii starts from 8 m/s, then after step time, wind speed increases to 14 m/s. In figure 3 this is shown

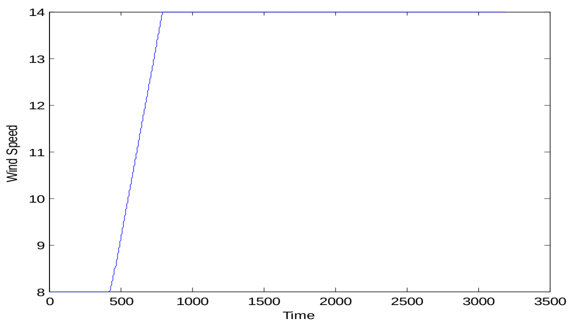

Figure 3: Simulink result of wind speed profile

After step time, as wind speed increase from initial value, the generator starts generating active power and the generated active power starts increasing smoothly (together with the turbine speed) to reach its rated value of 9 MW as shown in figure- 6.3(for generated active power) and figure- 4(for turbine speed)

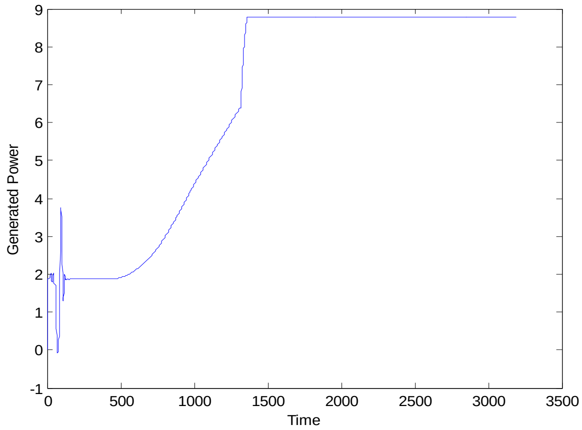

Figure 4: Simulink result of generated active power profile

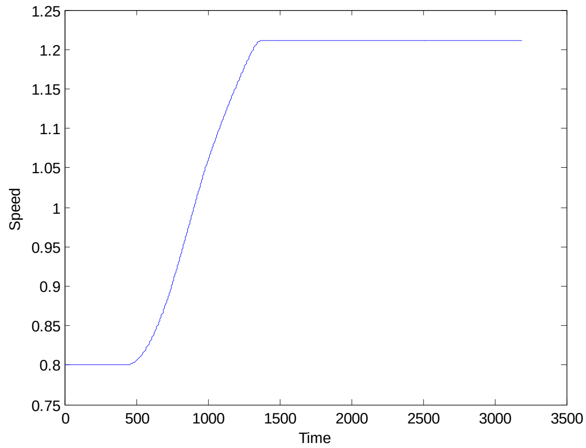

Figure 5: Simulink result of turbine speed profile

The pitch angle of the turbine blades is initially at zero degree, as DFIG reaches to its rated output power, pitch angle is increased (in order to limit the mechanical power) as shown in figure-6

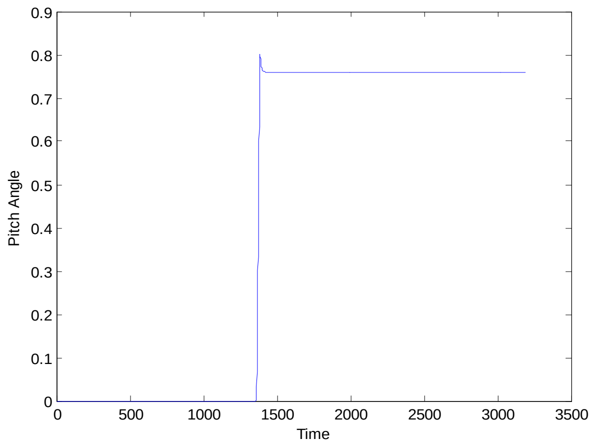

Figure 6: Simulink result of pitch angle profile

At nominal power, the DFIG absorbs reactive power (required for excitation of DFIG), so in the result it drops slightly which is sown in figure 7

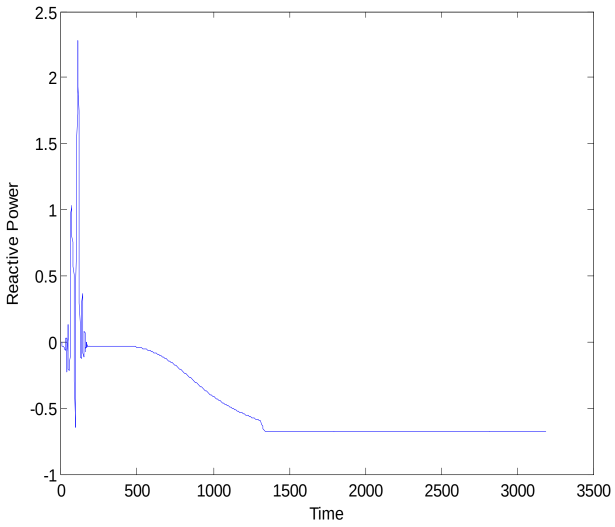

Figure 7: Simulink result of Reactive power profile

4. Impedance Measurement Results

For proposed islanding detection method, that is based on impedance measurement at the point of common coupling (PCC). With the help of impedance measurement block Impedance was measured for different loading condition. The impedance measurement block continuously measures impedance in terms of frequency. Obtained result for various switching conditions of breaker are shown in figure below.

4.1. Results of impedance measurement for Non Islanding condition

Figure 8 shows the result carried out for normally loaded condition with breaker in closed (non islanded) condition.

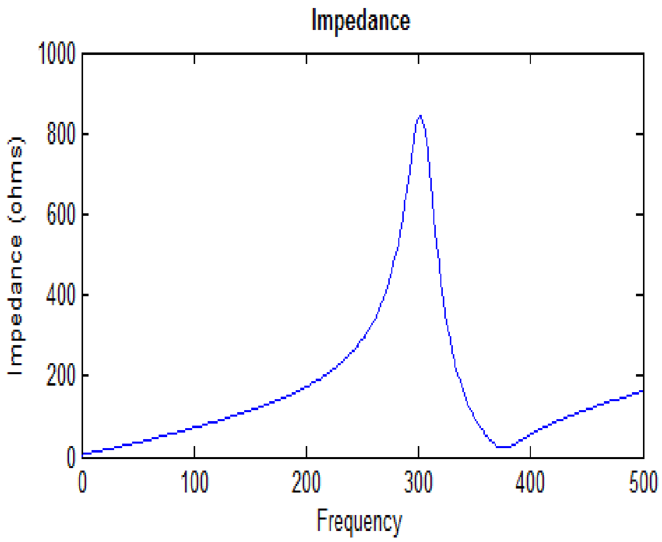

Figure 8: Simulink result of Impedance profile for normal loded condition with breaker in closed (non islanded) condition

Figure 9 shows the result carried out for sudden increased loding condition with breaker in closed (non islanded) condition.

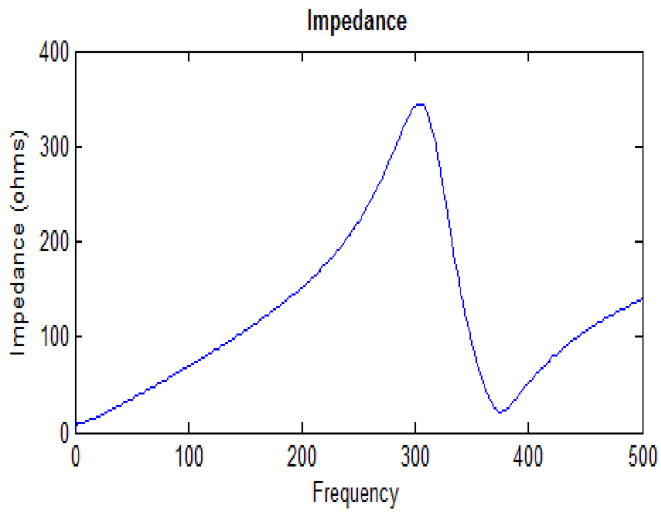

Figure 9: Simulink result of Impedance profile increased loding condition with breaker in closed (non islanded) condition

Figure 10 shows the result carried out for decreased loading condition with breaker in closed (non islanded) condition

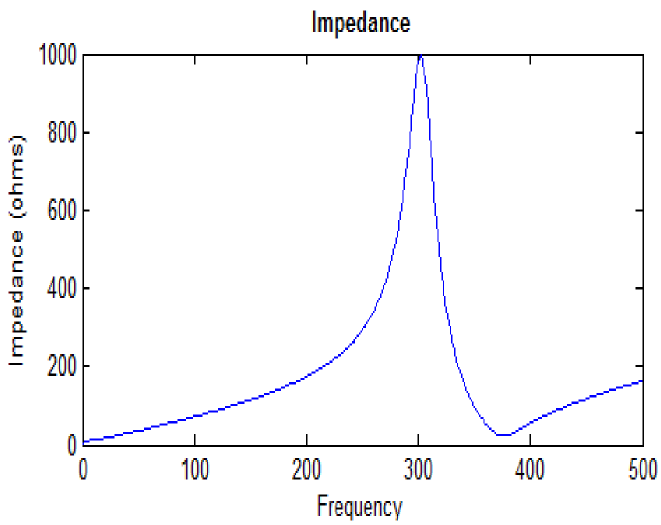

Figure 10: Simulink result of Impedance profile decreased loading condition with breaker in closed (non islanded) condition

4.2. Results of impedance measurement for Islandig condition

When the breaker is opened, in this condition DFIG comes in islanded condition because it is isolated from grid and still supplying the load that refers to islanding condition. As it has been previously found that if a DG is connected to the main grid, the system impedance seen by the DG will be very small. On the other hand, if it loses connection with the system, the impedance will be large [9][10][11][12],as shown in the figure 11.

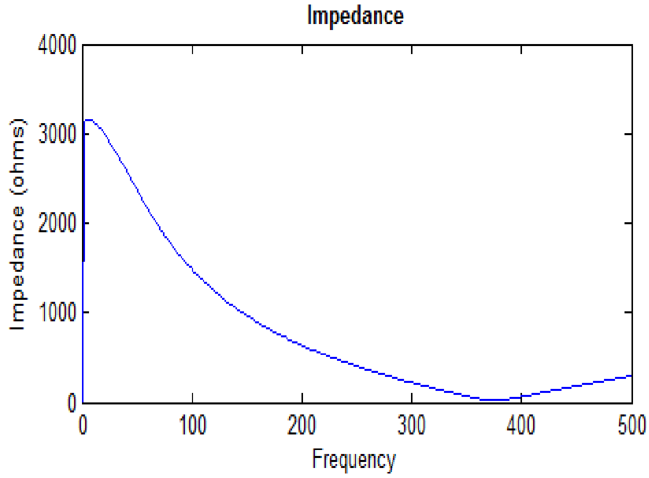

Figure 11: Simulink result of Impedance profile with breaker in open (islanded) condition.

5. Discussion

As seen from above results (figure 8, figure 9, figure 10 and figure 11), it is clear that if a DG is connected to the main grid, the system impedance seen by the DG will be very small. On the other hand, if it loses connection with the system, the impedance will be large. A possible way to detect an islanding condition, therefore, is to monitor the impedance on a continuous basis. The impedance measurement provides difference between an island condition and a non-island condition. The impedance may be one of the key indicators in disturbance conditions such as islanding process. Thus, during the islanding process, the impedance provides vital information which can be effectively used for islanding detection.

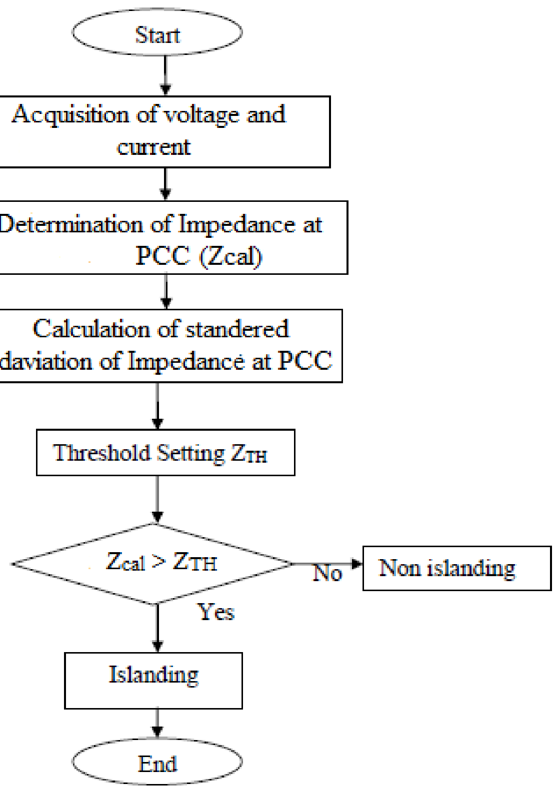

Figure 12: Proposed Algorithm for Islanding Detection

5.1 Proposed Algorithm for Islanding Detection

On the basis of results discussed above, an algorithm is proposed to identify that, whether islanding has occurred or not. In this impedance is considered as a tool to detect islanding condition

According to above algorithm we continuously measure voltage and current and hence variation in impedance (Z_{CAL}) at PCC, and a threshold value of impedance (Z_{TH}) is set. As islanding occurs, there is large variation in impedance. On islanding condition (Z_{CAL}) is very large as compared to non-islanding condition . If Z_{CAL} is greater than Z_{TH} , it refers to islanding condition, so islanding is detected.

6. Conclusion

This thesis describes and compares different islanding detection techniques. Fast and accurate detection of islanding is one of the major challenges in today's power system with many distribution systems already having significant penetration of DG as there are few issues yet to be resolved with islanding. Islanding detection is also important as islanding operation of distributed system is seen a viable option in the future to improve the reliability and quality of the supply

The proposed approach uses impedance for islanding detection. It has been observed that if a DG is connected to the main grid, the system impedance seen by the DG will be very small. On the other hand, if it loses connection with the system that is an islanding condition, the impedance will be large. So here impedance is used as one of the potential parameter for detecting islanding conditions in the DG. It is observed that the impedance for islanding and non-islanding cases is clearly separable and thus able to detect islanding events accurately. Thus the proposed method is highly effective for islanding detection of DG.

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