

Integration of Distributed Energy Sources in Power Systems

Hatem Zeineldin¹ and J. Kirtley²

¹Masdar Institute of Science and Technology, Abu Dhabi, ²Massachusetts Institute of Technology

Introduction

Distributed Generation (DG) can potentially increase the distribution system reliability and provide additional technical and economical benefits by allowing intentional islanding or so called micro-grid operation of DG. The current IEEE Standards do not address this issue but consider it as one of the tasks to be addressed in future revisions.

Micro-grids can generally be viewed as a group of micro-generation (DG) connected to the main utility grid. This concept provides a new idea for defining the operation of DG. It facilitates more creative and diverse schemes to meet the local requirements, in a flexible manner, with the small-scale generators and consumers closely integrated.

The project aims to address the challenges associated with the integration of renewable energy sources in power systems. This, will in turn, aid in breaking down the barriers facing wide spread integration of renewable energy sources in power systems and micro-grid operation.

Project Objectives

- Resolve problems associated with the integration of distributed generation in power systems.
- Develop control and protection schemes that will facilitate wide spread integration of micro-grids.
- Propose and develop solutions that could address the intermittent nature of renewable energy sources.
- Investigate how micro-grids could be included in a deregulated environment.

Why DG Micro-grids?

Many countries are trying to meet the targets set in the Kyoto Protocol to reduce greenhouse gas emissions. DG provides an attractive option to accomplish this task. Besides environmental benefits, technical and economical benefits could be achieved by allowing micro-grid operation of DGs

- Mitigate transmission congestion.
- Reduce power system losses
- Reduce greenhouse gas emission
- Reduce electricity market fluctuations.
- Provide peak shaving
- Might be capable of meeting future electricity demand growth at acceptable cost.
- DG can provide backup islands in case of utility outage and supply the critical loads "Micro-grids".
- Grid voltage support

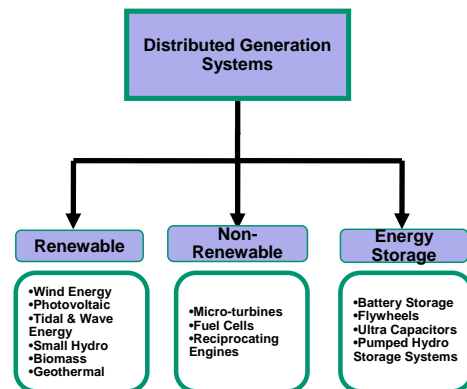


Figure 1: Distributed Generation Systems

Key Challenges

- Islanding detection
- Power system protection
- Power quality
- Intermittent nature of renewable energy sources
- Power system stability
- Voltage and frequency control.
- Electricity market operation.
- Micro-grids

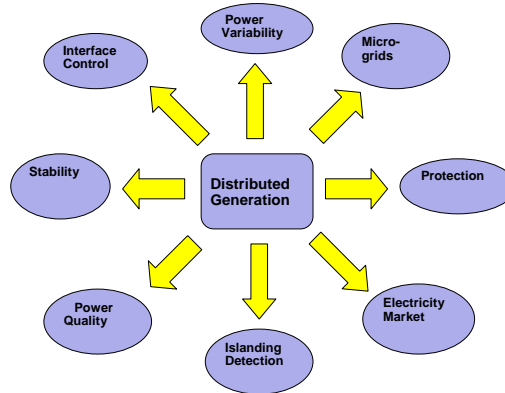


Figure 2: Challenges, under consideration, facing the integration of renewable energy sources

Islanding Detection of Inverter Based DG

In this work, we present a new islanding detection method for inverter based distributed generation. Although active islanding detection techniques have smaller non-detection zones than passive techniques, active methods could degrade the system power quality and are not as simple and easy to implement as passive methods. The islanding detection strategy, proposed in this work, combines the advantages of both active and passive islanding detection methods. The Distributed Generation (DG) interface was designed so that the DG maintains stable operation while grid connected and loses its stability once islanded. Thus, the Over/Under Voltage and Over Under Frequency protection method would be sufficient to detect islanding. The main advantage of the proposed techniques is that it relies on a simple approach for islanding detection, has negligible non-detection zone, and does not create power quality problems. The system was simulated on PSCAD/EMTDC and simulation results are presented to highlight the effectiveness of the proposed technique.

Islanding Detection Methods

There are three main categories for islanding detection methods which include passive, active and communication based methods. Passive methods rely on monitoring a certain parameter and then setting thresholds on the selected parameter. Despite its simplicity and easiness to implement, passive methods suffer from large Non-detection Zones (NDZ). Non-detection zones could be defined as the loading conditions for which as islanding detection method would fail to operate in a timely manner. Selecting suitable thresholds, for passive methods that rely on monitoring THD and voltage unbalance, becomes a hard and complex task since these parameters are system dependent. Active methods introduce deliberate changes or disturbances to the connected circuit and then monitor the response to determine an islanding condition. Active methods have smaller NDZ but on the other hand can degrade the power quality of the system. In addition, some active methods require the implementation of addition controllers which increases the complexity of the islanding detection method. Communication based methods have negligible NDZ but are much more expensive than the former methods.

System Under Study

The system, shown in Fig. 3, consists of a distribution network represented by a source behind impedance, a constant impedance load represented in terms of R-L-C and a 100 kW inverter based DG. The DG is designed to operate as a constant power source by setting the controller's active and reactive reference values to fixed values. The reactive power reference value (Q_{ref}) is set to zero, thus simulating a unity power factor DG operation. The DG interface has two sets of controllers, one for power regulation and the other for current regulation as shown in Fig. 4. The load is represented by a constant impedance load with an active and reactive power expressed as shown in (1) and (2).

$$P = P_o \left(\frac{V}{V_o} \right)^2 \quad (1)$$

$$Q = Q_o \left(\frac{V}{V_o} \right)^2 \quad (2)$$

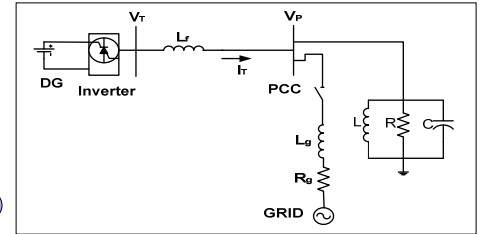


Figure 3: Study system for testing the proposed islanding detection technique

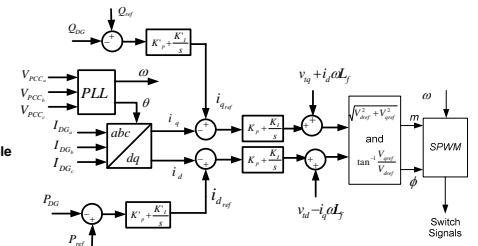


Figure 4: Distributed Generation Interface Control

Proposed Islanding Detection Technique

The proposed islanding detection technique in this work relies on the following:

- Setting the DG P_{ref} to be a function of the voltage.
- Setting the DG P_{ref} to be a tangent to (1) at rated conditions.

The general formula for calculating P_{ref} could be represented as follows

$$\frac{P_{ref} - P_o}{V - V_o} = \frac{dP}{dV} \Big|_{P_o, V_o} \quad (3)$$

$$P_{ref} = P_o + 2P_o(V - V_o) \quad (4)$$

The technique does not require any additional control blocks and does not interfere with the power system operation and thus avoiding any power quality problems. A simple and easy to implement islanding protection means such as the OVP/UVP method is implemented to detect the deviation in voltage once an islanding condition occurs. Figure 5 shows the performance of a DG when islanded at $t = 3$ seconds. The OVP/UVP method can easily detect islanding for the three presented loading cases.

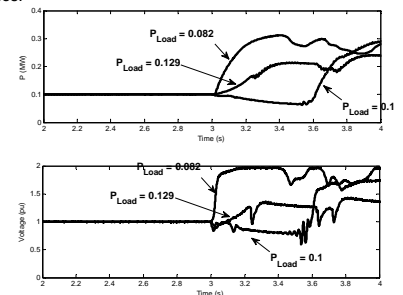


Figure 5: Active power and voltage during an islanding condition

Conclusion

Distributed Generation is an attractive option for accommodating rapid load growth in a flexible and cost effective manner. Large-scale integration of distributed generation is expected to have great environmental, technical and economical benefits on the long run. The project aims to break down the barriers facing the implementation of DG. This project will also provide guidelines to utility personnel for the integration of DG micro-grids in power systems.