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Instantaneous Energy-Based Passive Islanding Detection Technique for Microgrids: A Novel Approach

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Abstract

In recent years, microgrids have emerged as a promising solution to the increasing demand for reliable and sustainable electricity supply. Islanding is a critical issue in microgrids, which can cause severe damages to the connected loads and the grid itself. Therefore, the detection of islanding is crucial for the safe and efficient operation of microgrids. This research paper proposes a novel passive islanding detection method for a microgrid using instantaneous energy. The proposed method is based on measuring the rate of change of instantaneous energy in the microgrid during normal and islanding conditions. The simulation results show that the proposed method can detect islanding events with high accuracy and sensitivity, even in the presence of noise and disturbances. The proposed method can also be easily implemented in practical microgrid systems with low-cost hardware and minimal communication requirements.

Keywords: *— Microgrid, Islanding, Detection, Instantaneous Energy, Rate of Change.*

INTRODUCTION

Microgrids are localized energy systems that integrate renewable energy sources, energy storage devices, and load demand in a small geographical area. The microgrid operates in parallel with the main grid and can operate in islanded mode during grid disturbances. However, islanding can cause several problems, such as voltage and frequency instability, overvoltage, and undervoltage, which can damage the connected loads and the grid itself. Therefore, islanding detection is critical for the safe and efficient operation of microgrids.

Several islanding detection methods have been proposed in the literature, including passive, active, and hybrid methods. Passive methods are based on measuring the electrical parameters of the microgrid, such as voltage, current, and frequency, during normal and islanding conditions. The passive methods do not require additional hardware or communication, but their accuracy and sensitivity are limited. Active methods inject a specific signal into the microgrid and measure its response to detect islanding. However, active methods require additional hardware and communication, which increases the cost and complexity of the system. Hybrid methods combine passive and active methods to improve the accuracy and sensitivity of the islanding detection.

This research paper proposes a novel passive islanding detection method for a microgrid using instantaneous energy. The proposed method measures the rate of change of instantaneous energy in the microgrid during normal and islanding conditions. The instantaneous energy is defined as the product of the instantaneous voltage and current. The proposed method does not require additional hardware or communication, and it can detect islanding events with high accuracy and sensitivity.

The rest of the paper is organized as follows. Section 2 describes the proposed islanding detection method in detail. Section 3 presents the simulation results and analysis. Section 4 discusses the advantages and limitations of the proposed method. Section 5 concludes the paper.

PROPOSED ISLANDING DETECTION METHOD

The proposed islanding detection method is based on measuring the rate of change of instantaneous energy in the microgrid during normal and islanding conditions. The instantaneous energy is defined as the product of the instantaneous voltage and current. The rate of change of instantaneous energy is calculated using a first-order difference equation as follows:

$$\Delta E = E[n] - E[n-1]$$

where $E[n]$ is the instantaneous energy at time n, and ΔE is the rate of change of instantaneous energy.

The proposed method consists of two stages: training stage and detection stage.

Training Stage:

During the training stage, the proposed method calculates the mean and standard deviation of the rate of change of instantaneous energy under normal and islanding conditions. The training stage is performed during the commissioning of the microgrid and can be repeated periodically to account for changes in the microgrid parameters.

The steps of the training stage are as follows:

1. Measure the instantaneous voltage and current of the microgrid during normal operation.

2. Calculate the instantaneous energy using the product of the voltage and current.

3. Calculate the rate of change of instantaneous energy using the first-order difference equation.

4. Record the rate of change of instantaneous energy for a certain period.

5. Calculate the mean and standard deviation of the rate of change of instantaneous energy under normal operation.

6. Repeat steps 1-5 for islanding conditions.

7. Store the mean and standard deviation values for normal and islanding conditions.

Detection Stage:

During the detection stage, the proposed method continuously monitors the rate of change of instantaneous energy in the microgrid. If the rate of change of instantaneous energy exceeds a threshold value, the proposed method triggers an islanding event. The threshold value is calculated based on the mean and standard deviation values obtained during the training stage.

The steps of the detection stage are as follows:

1. Measure the instantaneous voltage and current of the microgrid.

2. Calculate the instantaneous energy using the product of the voltage and current.

3. Calculate the rate of change of instantaneous energy using the first-order difference equation.

4. Compare the rate of change of instantaneous energy with the threshold value.

5. If the rate of change of instantaneous energy exceeds the threshold value, trigger an islanding event.

6. Repeat steps 1-5 continuously.

SIMULATION RESULTS

To evaluate the performance of the proposed islanding detection method, a microgrid model was developed in MATLAB/Simulink. The microgrid consists of a photovoltaic (PV) array, a battery energy storage system (BESS), and a load. The PV array generates power during the day, and the BESS supplies power during the night or during cloudy days. The load demand varies randomly.

The islanding events were simulated by disconnecting the microgrid from the main grid abruptly. The proposed islanding detection method was compared with two existing islanding detection methods: the passive frequency shift (PFS) method and the active frequency drift (AFD) method.

The simulation results show that the proposed islanding detection method can detect islanding events with high accuracy and sensitivity. The false positive and false negative rates were significantly lower compared to the PFS and AFD methods. The proposed method also showed robustness to noise and disturbances.

ADVANTAGES AND LIMITATIONS

The proposed islanding detection method has several advantages over existing methods. The method is passive and does not require additional hardware or communication, which reduces the cost and complexity of the system. The method is also simple and can be easily implemented in practical microgrid systems. The proposed method showed high accuracy and sensitivity in detecting islanding events, even in the presence of noise and disturbances.

However, the proposed method has some limitations. The method relies on the instantaneous energy measurement, which may not be accurate under non-sinusoidal and unbalanced conditions. The method also requires a training stage, which may not be feasible for some microgrid systems. The method may also not be suitable for detecting islanding events with slow dynamics.

CONCLUSION

This research paper proposed a novel passive islanding detection method for a microgrid using instantaneous energy. The proposed method measures the rate of change of instantaneous energy in the microgrid during normal and islanding conditions. The simulation results showed that the proposed method can detect islanding events with high accuracy and sensitivity, even in the presence of noise and disturbances. The proposed method can also be easily implemented in practical microgrid systems with low-cost hardware and minimal communication requirements. However, the proposed method has some limitations and requires further investigation to improve its performance under non-sinusoidal and unbalanced conditions.

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