Distribution Grid Monitoring through Pilot Injection and Successive Interference Cancellation

Surena Neshvad, Interdisciplinary Centre for Security, Reliability and Trust , University of Luxembourg, 4, rue Alphonse Weicker, L-2721 Luxembourg, (+352) 46 66 44 5378, surena.neshvad@uni.lu

Symeon Chatzinotas, Interdisciplinary Centre for Security, Reliability and Trust , University of Luxembourg, 4, rue Alphonse Weicker, L-2721 Luxembourg, (+352) 46 66 44 5767, symeon.chatzinotas@uni.lu

Jürgen Sachau, Interdisciplinary Centre for Security, Reliability and Trust , University of Luxembourg, 4, rue Alphonse Weicker, L-2721 Luxembourg, (+352) 46 66 44 5301, juergen.sachau@uni.lu

Overview

Due to the push for renewable energy in the last decades, European countries have witnessed an exponential growth of Distributed Generation (DG) on the medium voltage network. An increasingly large portion of the electricity demand is fed in through the distribution grid, whose good health and operational status will be more and more important for guaranteeing grid stability. In Luxembourg, the distribution network is sparsely monitored and controlled, thus instabilities arising due to line overvoltage or DG malfunctioning are not easily detected and resolved [1]. This research discusses a novel and low infrastructure methodology for online monitoring of the distribution grid. The necessity of such a tool will be increasingly necessary in order to guarantee the stability, reliability and security of the power network, as a larger and larger portion of the energy demand will be satisfied by DG in future years.

Method

The proposed method relies on reprogramming the DG inverter’s Pulse Width Modulator (PWM) in order to overlap broadband Pseudo-Random-Binary-Signals (PRBS) [5] on top of the fundamental [2]. The PRBS is used as a pilot signal for identification of its propagation path [4]. At the transformer substation, the receiver, who knows in advance each inverters unique code, is continuously monitoring for the code. Once the code has been detected, the transfer function of the propagation path is computed through cross-correlation of the code with the voltage and current swings at the transformer. Using orthogonal codes, multiple senders can inject codes simultaneously, and their respective interference is cancelled. But for situations with numerous inverters, this does not hold true anymore. In order for detection to operate properly when many inverters are injecting PRBS signals simultaneously, the Successive Interference Cancellation (SIC) technique is applied to increase scalability, by reducing maximally the interference between the multiple codes of the different inverters. This paper describes the system identification method, discusses the case of multiple simultaneous emitters, and compares the accuracy of the channel estimation using orthogonal PRBS codes with and without SIC application.

Results

Simulations are performed with grid parameters obtained from Creos, the Luxemburgish utility provider. Identification of the line parameters is accurate when the number of simultaneous injections is low. The receiver at the transformer substation is able to detect the codes from each inverter, even if they are injected simultaneously, and the transfer function estimation through correlation is close to the theoretical value for a broad frequency range. With increasing number of injectors, the results degrade progressively, and the orthogonal nature of the code is not enough to cancel out noise orders of magnitude larger than it. Using SIC, system identification shows significantly better results and systems with up to ten inverters injecting simultaneously can be detected and characterized. Nevertheless, if system parameters are not set optimally, inaccurate results might be obtained. Therefore, careful planning is required for setting each injectors strength and location in order to obtain optimal results.

Conclusions

A full scale distribution grid monitoring tool is described in this paper. The proposed method doesn’t require external communication tools, it is simple and easy to operate. The DG inverters are reprogrammed for code injection, and the only additional hardware required infrastructure is the receiver at the transformer substation, which will be constantly monitoring for the PRBS codes, and applying signal processing for characterizing the network. The results are greatly improved through SIC, and the method can be applied to complex grid structures. Deployment of this grid identification tool would enable a tighter control and monitoring of distribution grid, which due to its current and future explosion in complexity will be prone to renovation and restructuration in order to support more renewable energy sources. Laboratory implementation and experiments with custom-controlled inverters is in progress, and initial experiments have shown promising results.

References

[1] P. Heskes, “Minimizing the Impact of Resonances in Low Voltage Grids by Power Electronics based distributed Generators”, PhD, Technische Univerity Eindhoven, April 2011

[2] S. Neshvad, S. Chatzinotas, J. Sachau, “Online Determination of Grid Impedance Spectrum through Pseudo-Random Excitation of a Pulse Width Modulator”, International Conference on Renewable Energies and Power Quality, April 2014

[3] L. Qu, J. He, C. Assi, “Understanding the Benefits of Successive Interference Cancellation in Multi-Rate Multi-Hop Wireless Networks”, Transactions on Communications, IEEE Volume: PP , Issue: 99

[4] J.P. Rhode, A.W. Kelley, M.E. Baran, "Complete Characterization of Utilization-Voltage Power System Impedance Wideband Measurement", Industrial and Commercial Power Systems Technical Conference, 1996 *IEEE*

[5] R.N. Mutagi, “Pseudo Noise Sequences for Engineers”, IEEE Electronics and Communication Engineering Journal, April 1996