Islanding and Resynchronization Procedure of a University Campus Microgrid

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SUMMARY

The increasing energy demand, the operation of the grid close to its stability limits, and the slow and costly expansion of the transmission infrastructure to unserved regions are the main drivers for the introduction of the microgrid concept. Microgrids are small-scale controllable low-voltage electrical systems, which incorporate Distributed Energy Resources (DER) and loads in their design. The most important feature of a microgrid is that it can operate in both, grid-connected or islanded mode.

During the last decade, there is an increasing interest amongst the research society to explore the benefits and overcome the barriers for integrating microgrids. Due to this reason, university campuses are commonly chosen for the development of microgrids, which can be utilized as Living Laboratories by the researchers. The design and implementation of such a microgrid framework in a university campus is the objective of the 3DMicroGrid, which is an ERANETMED funded project. The resulted microgrid will be enhanced by novel control methodologies in order to ensure a stable and smooth operation (either in grid-connected or islanded mode), maximize the utilization of renewables and improve the resilience and the power quality of the microgrid.

The main contribution of this paper is the development of a control methodology for the smooth and seamless transition from the grid-connected to the islanded mode and vice-versa (resynchronization). First, the paper will present the possible reasons that can cause the transition of the microgrid to the islanded mode. Then, a novel optimization approach will be presented for ensuring the smooth and timely transition to islanded mode. Further, all the conditions which must be satisfied in order to reconnect the microgrid back to the main grid will also be included in this paper. It is worth mentioning that all these requirements will be integrated into the controller scheme for automating the islanding and resynchronization procedure.

The main benefit for the Distribution System Operator (DSO) for including microgrids in the main grid, is the consideration of “flexible loads” in the system. This means that these loads can be left out whenever is necessary (e.g., in the case of a contingency) and reconnect back when the operation is normal, without severe economic and social impacts. Therefore, one reason for going into islanded mode can be upon request from the DSO (such as for load-shedding purposes). In addition, the microgrid should be able to transit to islanded mode at will, in case it detects any abrupt voltage or frequency oscillations in order to maintain the integrity of the microgrid. Detailed explanation of all these reasons and specific set-points for the transition will be provided in the full paper.

The requirements for the resynchronization, which will be considered in this paper, are the same for connecting any active component to the power system. Thus at the Point of Common Coupling (PCC) the maximum frequency deviation must be less than 0.1 Hz, the voltage angle difference less than 20° and the voltage magnitude difference must be less than 5%. If these requirements are satisfied, then the resynchronization procedure of a microgrid can be perform in a smooth and secure way. In the final paper, guidelines for how the microgrid can satisfy these criteria will be explained in detail.

Apart from defining and implementing the requirements for the transition from the grid-connected to the islanded mode (and vice versa), this paper is mainly concentrated in preparing the microgrid for a smooth and fast transition between these modes. More specifically, this procedure is focused on severe disturbances where the microgrid needs rapidly to switch to islanded mode. Under such circumstances, it is very critical to maintain the energy balance within the microgrid (to secure the smooth transition to islanded mode within less than 1 s) with the minimum load shedding. Such an objective can be achieved by utilizing the flexibility of the controllable loads and the fast DER. Thus, the controllable loads are categorized into essential and non-essential loads. The former represents the loads which ideally should be satisfied at all times, without any curtailments taking place. The latter are the loads which can be cut-off in case of emergency. Furthermore, to keep the energy balance within the microgrid is also necessary to consider the energy units as well in this procedure. The microgrid under consideration includes a diesel generator, a battery storage system (BSS) and photovoltaic (PV) systems. The DER that are integrated through power electronics converter allow the fast management of these devices which is a crucial flexibility that can contribute for minimizing the power unbalance during the transition.

By taking into consideration both controllable loads and the DER, an optimization algorithm can be developed. The objective function of the optimization is to ensure the energy balance between the generation and the demand site in order to ensure the smooth transition to islanded mode. In other words, the following cost function must be satisfied:

$$\textit{Objective function} = \min(\Delta P) \qquad (1),$$

where

$$\Delta P = P_{GEN} - P_{LOAD} \qquad (2).$$

P_{GEN} is the total instant energy production of the microgrid's DERs and P_{LOAD} is the overall demand of the campus.

However, as any optimization problem, the cost function of (1) is going to be subject to some constrains. The most important ones are the following:

1) Satisfaction of maximum allowed load in case of higher demand compared to the energy production.

2) Minimize the curtailment of essential loads. It should take place only when all the non-essential loads are cut-off and the total load is still high.

3) Control the energy production from BSS and PVs at the event of excess energy production. A smart use of the BSS as a load should be considered depending on the instant state-of-charge (SOC).

4) The curtailment of the single-phase controllable loads must be done in a way to minimize the asymmetric loading conditions of the microgrid.

A novel Mixed Integer Linear Programming (MILP) formulation will be developed for defining the states (on/off) of the controllable loads and the set-points to the DERs. Furthermore, the solution should be computed and applied to the all microgrid components in a timely manner. A detailed explanation of the formulation of the proposed controller according to the objective function of (1), will be presented in the full paper.

It is worth mentioning that all the aforementioned requirements and control methodologies will be designed and tested using analytic simulations for the microgrid operation. The simulation results will demonstrate the effectiveness of the proposed solutions for the university campus microgrid in order to ensure the smooth and timely transition between different operation modes.