LOAD TYPE IMPACTS ON FREQUENCY CONTROL OF MICROGRIDS IN TRANSITION FROM GRID-CONNECTION TO ISLANDING

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ABSTRACT

This paper analyzes the operation of an autonomous microgrid when frequency-dependent loads are available within the microgrid. The main focus in this paper is the impact of different load types on the behaviour of the microgrid in transition from grid-connection to islanding. It is shown that the same control strategy has different impact on the system frequency dynamics when the load type varies. Typical load models such as constant power, frequency-dependent and composite loads are analyzed and simulated. The simulation results indicate the salient role of the load type on the behaviour of microgrid control schemes.

INTRODUCTION

Pollutions and green house gases are side-effects of electric power generation from fossil fuels. Meanwhile, distributed generation and energy storage using renewable energies, can potentially help to solve environmental problems such as climate change and energy crisis. In this regard, microgrid paradigm is evolving as a promising solution to interconnecting a set of Voltage Source Converters (VSCs)-interfaced distributed energy resources such as photovoltaic arrays, wind turbines, fuel cells, microturbines, energy storage devices like batteries and flywheels, and controllable loads with the utility grid [1]–[2]. A microgrid can be thought of as a controllable subsystem to the utility, it can be connected with the utility grid, or it can operate isolated from the main grid in case of disturbances or faults. There are many technical issues related to microgrid operation, including frequency control during islanded operation or managing the parallel VSCs in islanding operation so as to achieve high performance of power and voltage regulations within the microgrid [3]-[5].

A microgrid has more controlled variables than the common used synchronous generator. VSCs as the interface between distributed energy resources and the ac distribution system can be operated in active power-reactive power (PQ) mode, active power-voltage (PV) mode, voltage-frequency mode (Vf), etc. The control strategy selection has large impact on the microgrid system performance. When a microgrid is connected to a utility grid, the frequency excursion due to the load variations is not remarkable, but for an autonomous microgrid, stabilization of the frequency in its nominal value is an important issue [6]-[8].

Control of a VSC or management of sharing power in parallel VSCs operations are discussed in literature [9]-[11]. For a single VSC (a unique distributed energy source), voltage–frequency (V-f) control scheme in isolated operations or active power–reactive power (P-Q) control scheme in grid-connected operations are used. For parallel VSCs (multiple energy sources), the active power–frequency droop control and reactive power–voltage droop control may be used to share the active power and reactive power in isolated operations. The deficiency of these control schemes is the changes of voltage with the reactive power as the load varies.

In [7] a new active power and voltage (P-V) control scheme for the VSCs that operate in the islanding mode, which can regulate both the active power and the magnitude of the voltage of the VSC, is discussed. The proposed control scheme can be applied in droop control method to handle the active power sharing among parallel VSC-interfaced distributed energy resources operated in the islanding mode. The reactive power output from the power regulated VSCs can be set to some predefined values because the VSC interfaced distributed energy sources have reactive power generation capabilities. The reactive power output from the voltage-regulated VSC is unregulated and can change with the load. In this study a typical R-L load is used in the islanding mode.

In [8] different control schemes scenarios are discussed, for example; all the VSCs operating in Vf mode; one VSC operating in Vf mode and the others in PQ mode; and a group of VSCs operating in Vf mode and another group of VSCs in PQ mode.

In analyzing different control strategies reported in the literature, the main focus is on the performance of the proposed control strategy, without significant concentration on the response of different load types to the same control scheme. Load model and combination of different loads has a remarkable impact on the same control strategy. In many cases the considered loads are of constant impedance type. The analysis is more complicated when frequency-dependent loads are used, because the duration and the extent of frequency excursions are important for such loads, especially from power quality point of view.

In [6], the dynamic behavior of a microgrid is evaluated considering only three-phase balanced operation and two load types: constant impedance loads (power dependent on frequency and voltage) and motor loads (an asynchronous motor with constant mechanical torque). It is shown the loads characteristics influence greatly the dynamic behavior of the microgrid, mainly in short-circuit conditions.

Controllable loads, available for load-shedding have also been modeled, with the amount of load to be shed defined from the amplitude of the grid frequency deviation. In [6], the impact of the load characteristic on the microgrid control system behavior is not analyzed directly.

In this paper typical frequency control strategies in a microgrid used to smooth transition from grid-connected to autonomous operation are discussed. A concise explanation of different load models commonly used in microgrids is also presented. The impact of different load models on the system frequency dynamics from grid-connection to islanding is simulated in MATLAB/Simulink environment [12].

FREQUENCY CONTROL SCHEMES OF A MICROGRID

To a certain extent the active and reactive power which is supplied by a VSC interfaced microsource, can be controlled independently. PQ, PV, and Vf control schemes are the common schemes which are applied for VSC interfaced microsources. One of the main problems with isolated systems is the presence of some low-response and inertia-less microsources which necessitates putting some compensating devices such as battery storage on dc link to realize fast load tracking. It is worth noting that the main assumption made with all the microsources is that they have limited ratings.

In order to developing a model for voltage-frequency controlled DG, two control loops are needed. Voltage control loop and frequency controller. Frequency controller can be a PI controller which is driven by subtraction of system frequency from the reference frequency, i.e., 50 Hz. Frequency of the system can be measured by a PLL, and to get a better performance, a feed-forward controller can be implemented.

LOAD MODELS

In power system analysis, all power system components are represented by their models. Generally, detailed data about components such as generators, transformers, and transmission lines are available, and accurate models can be obtained for them. However, corresponding data for individual loads are not always available, which makes the modeling of loads an important area of research. Increasingly nonlinear dynamic loads have been connected into power systems; such as variable speed drives, robotic factories and power electronics loads. This adds to the complexity of load modeling. In distribution systems, there are often multiple loads connected to a single bus. Normally the power of individual load is not measured or not available, but the total power transmitted through the bus is measured. In these cases, the loads can be considered as one composite load, which consists of static loads and dynamic or nonlinear loads. In recent years, many different techniques have been proposed to model such loads. However, most of them are based on an assumed load equation and the parameters of the equation are estimated through curve fitting. Because of the complexity of modern loads (for example, power electronics loads), the assumed models may not capture power, frequency, and voltage phenomena simultaneously and accurately. It is necessary to investigate new load modeling techniques and establish accurate load models for power system stability analysis [13].

SIMULATION RESULTS

A sample network is set up in MATLAB/Simulink environment. It consists of a microgrid including different microsources feeding a composite load. The microgrid is connected to the utility grid by a switch.

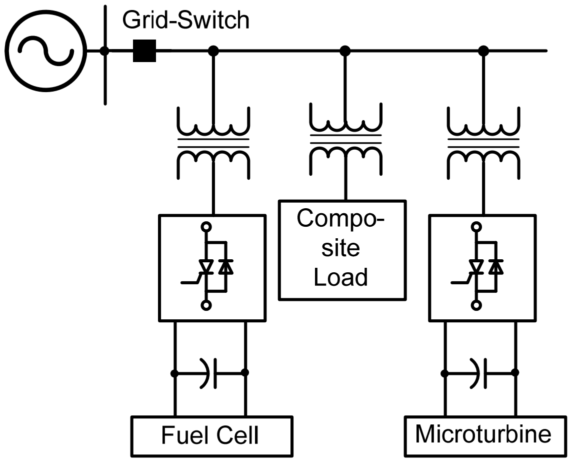

Figure 1: Sample microgrid network.

Composite load is composed of a constant power load (50 kW) and an asynchronous motor (37 kW). Asynchronous motor is simulated in full detail [14]. The load is supplied by the fuel cell through VSC and also the utility grid, up to 0.2 s, then the "grid-switch" is opened and the load is fed only by the fuel-cell. Figure 2 shows the frequency variations from t=0 to t=0.4s.

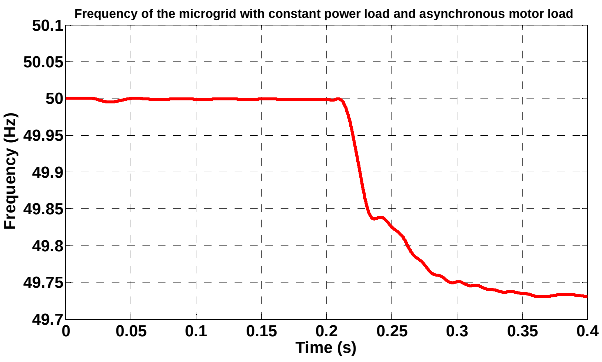

Figure 2: Frequency of the microgrid (composite load=constant power load + asynchronous motor).

As can be deduced from this figure, transition from grid-connected to the autonomous operation causes the frequency of the microgrid to be decreased.

Figure 3 shows the same case but the load type is constant power and the asynchronous motor is removed. As can be seen, the frequency is decreased to a less extent after disconnection of the grid.

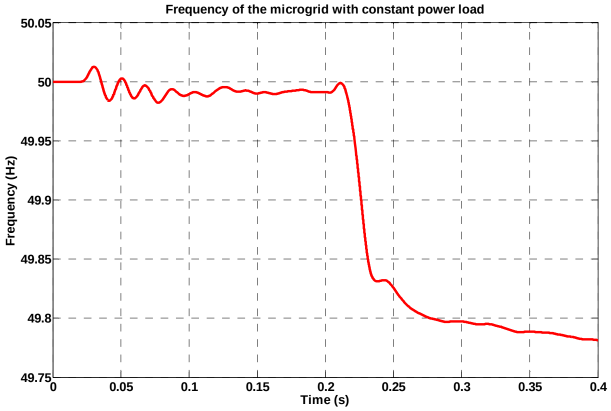

Figure 3: Frequency of the microgrid with constant power load.

Figure 4 shows the frequency, when the load is composed of an asynchronous motor (75 kW). As can be deduced from this figure, the frequency is increased after opening of the "grid-switch". Comparison of the Figures 2-4, reveals the importance of the load type on the frequency of the microgrid after transition to autonomous operation.

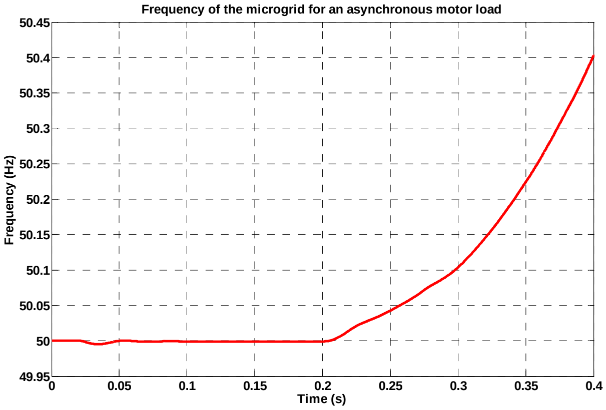

Figure 4: Frequency of the microgrid with asynchronous motor load.

Figure 5 shows a new sample network that resembles VSC-HVDC, i.e., the grid is connected to the microgrid by two back-to-back VSCs. This helps to isolate the disturbances from grid side to the microgrid. Figure 6 shows the frequency variations of the sample system of Figure 5, when the grid is disconnected at t=0.2s. As can be deduced from this figure the frequency excursions before and after microgrid autonomous operation is negligible. The frequency is stabilized at approximately 49.92 Hz.

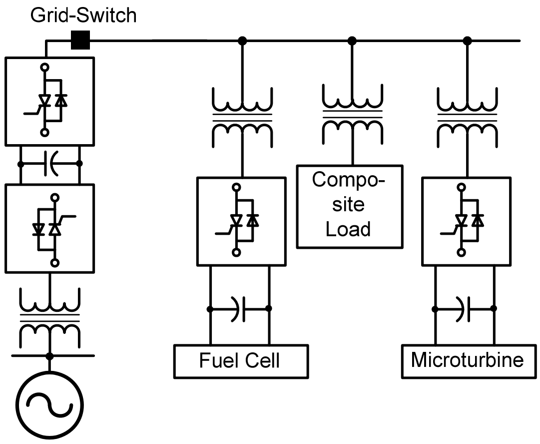

Figure 5: Sample microgrid using back-to-back VSCs

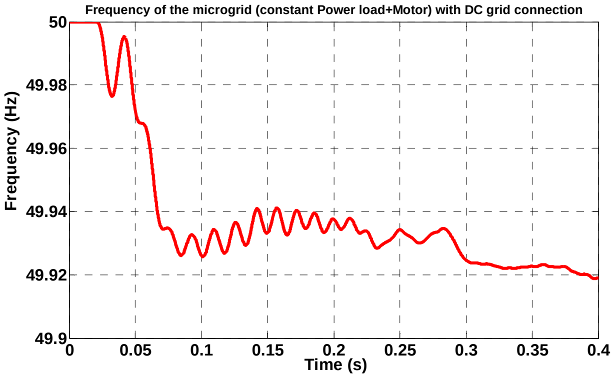

Figure 6: Frequency of the sample system in Figure 5.

Figure 7 shows the same result, but the load is a constant power type. As figure shows, there is no significant difference with Figure 6.

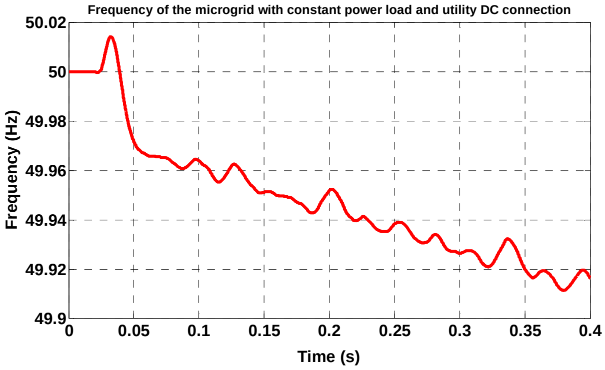

Figure 7: Frequency of the microgrid of Figure 5 with constant power load.

Figure 8 shows the frequency of the microgrid of Figure 5 when the load is an asynchronous motor. As can be seen from this figure, the frequency undergoes to some oscillations after separation of the grid at t=0.2 s. For better demonstration, the simulation time is increased to 0.8 s and the isolation of the microgrid is performed at t=0.4 s. Figure 9 shows the results, the frequency is decreased to 49.4 Hz.

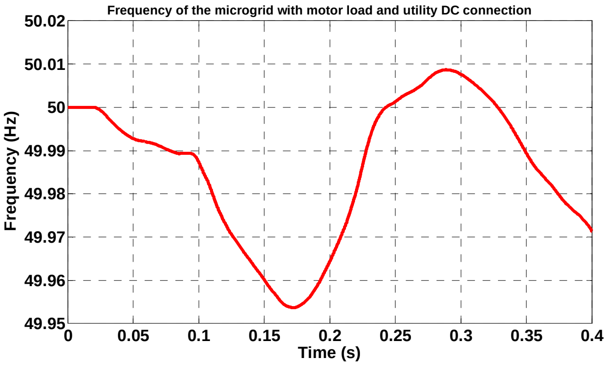

Figure 8: Frequency of the microgrid of Figure 5 with asynchronous motor load for 0.4s simulation time.

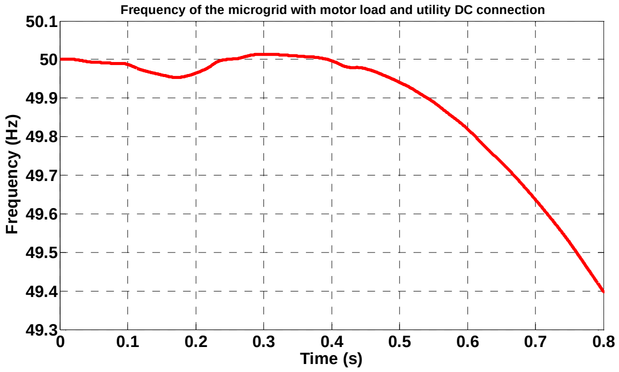

Figure 9: Frequency of the microgrid of Figure 5 with asynchronous motor load for 0.8s simulation time.

CONCLUSION

This paper presents the impact of different load types on the performance of the control system of the microsources of a microgrid. It is shown that composite loads comprising of constant power and asynchronous motor loads have approximately the same effect on the system frequency compared with the case of only constant power loads. However, when the composite load is composed of motor loads, the frequency excursions are different, especially after isolation of the microgrid from the utility grid. It is also demonstrated that if the grid is connected to the microgrid by using back-to-back converters, then the impacts of grid isolation on the frequency is mitigated. It can be concluded that the performance of different control schemes of VSCs within a microgrid should be evaluated for different combinations of composite loads.

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