Simulation and Evaluation of micro-grid synchronization with main network

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ABSTRACT: Nowadays, due to their high reliability, Micro-grids have improved dramatically. Micro-grids work in two main modes: islands and a network connection. Under certain conditions, the micro-grid is connected or disconnected to the main network. Synchronization of a Micro-grid with the main network must be done when the voltage of micro-grid is in synchronization with the voltage of main network. Phase-locked loops are responsible for detection of phases of micro-grid and main network voltages and when the two voltages were synchronized, micro-grid is connected to the main network. This article studies and simulates the connection of a micro-grid to the main network when the voltages are synchronized and asynchronized.

Keywords: Micro-Grid, Phase Angle, Phases Locked Loops, Synchronization.

INTRODUCTION

Using new control methods besides distribution generated sources by considering levels of security, quality, reliability, and accessibility of power distribution networks, generally leads distribution networks from being subordinate to being active and dynamic. Indeed, active distribution networks leads to a new concept called micro-grid network. Micro grids are low-voltage networks that include distributed generation resources or the DER, like micro turbine, solar cells and storage batteries as the controllable power load with a strong control system (Changhee Cho et al, 2011; Prakash K Ray et al 2011; Kroposki B et al, 2008; Rocabert Joan et al, 2011). Synchronization of parts of the power system is one of the major issues in the system. In order to synchronize the system with an power system, estimating phase operation must first be done, and then based on the estimated phase, synchronization is taken place. Estimating the phase is carried out by phase locked loops, which are used when connection of a structure to the network is required. Micro-grids as part of the power system that have the ability to separate from the network should do something in order to connect to the network synchronism again. In this paper, we consider a simple model of micro-grid (Yazdani D et al, 2008; Molina Marcelo Gustavo et al, 2011), a micro-grid is with a power network simulation. Using a PHASE LOCKED LOOP, modes of the micro-grid connection to a network are fully reviewed.

Micro Grid

Using new control methods besides distribution generated sources by considering levels of security, quality, reliability, and accessibility of power distribution networks, generally leads distribution networks from being subordinate to being active and dynamic. Indeed, active distribution networks leads to a new concept called micro-grid network. Micro grids are low-voltage networks that include distributed generation resources or the DER, like micro turbine, solar cells and storage batteries as the controllable power load with a strong control system. Figure (1) shows the general schematic of a micro-grid network.
As shown in Figure (1), this network is connected to the global medium voltage network, and has the ability to work when separated from the network. From the perspective of the consumer, a micro-grid has the ability of supply of both electricity and heat. On the other hand, increasing the quality of electricity, increase reliability, reduce emissions, reduce the voltage drop and energy costs are also regarded. Micro grid consists of a coordinated action between demand response and production by distributed generation sources besides maximizing the benefit received by the subscribers and the upstream network (Barklund E et al, 2008).

**Modes of a Micro-Grid**

A simple sketch of a micro-grid structure and synchronization system is shown in Figure (2). As it can be seen, Micro-Grid can be modeled as a source of power and as a demand (Yun Wei L et al, 2009).

Micro Grid is connected to the main network by a static key and synchronization system. It should be noted that if you want to separate micro-grid from the core network, the system model is like Figure (3). Besides the static key an external voltage source should be located with a voltage source inverter, in order to provide the micro-grid's lack of power when it is separated from the network and to prevent micro-grid instability.

**Connection to Network mode**

Under such circumstances, in addition to the micro-grid power sources, core network also provides loads in the Grid Micro which is more than Grid micro-production at the moment; so that the power balances between load and generation micro-grid resources can be established (Yazdani D et al, 2008). In the main connection mode, the S static key is to follow the grid voltage, and if voltage is abnormal, micro-grid is isolated from the main network. In this paper, separation of Micro Grid is not studied, and only the aspect of synchronization of the micro grid with the main network has been studied.
A Micro-Grid performance is done in three different modes, including mode of network connectivity, and the island state and a transient state. Transient mode includes fluctuations of voltage and current at the time of connection and separation of micro-grid from home network to reach steady mode.

**The island mode**

Whenever there is an error in the main network, or the direction of micro-grid power flow to the main network changes, the static S key, separates micro grid from the main network. When Micro-grid is separated from the main network, to island mode in a stable state to continue to work and need not be repeated outages. Micro-grids can be repeated if needed to provide assistance to foreign source. Load management programs should be based on previously determined according to repeated allergies, blackout dates apply at certain times. For the micro-grid power generation, renewable energy sources are used. These sources using power electronic converters are connected to the micro-grid. The island became the source voltage and frequency based on feedback frequency and voltage can be independently controlled from the network. It mean power resources have no communication to execute the control process. This independent control is performed by high-order power control loop methods (Molina M.G et al, 2011), or falling method of characteristics (Barklund E et al, 2008). The control of voltage and frequency is in fact control of active and reactive powers.

**Transient Mode**

When the voltage of the network is impaired, static S key is opened and separates the micro-grid from the network. In this situation, a transient occurs for Micro Grid. Also, once Micro-Grid wants to connect to the main network, transient occurs for micro-grid. This paper examines how transient and transient oscillations decreases when it is connected to a micro-grid home network have been discussed. If micro Grid connection to the core network is not taken place under certain conditions, transient mode may occur and lead to micro-grid instability.

**Synchronization system**

An important task should be done before connecting any power resource to the network is synchronization of source voltage with network voltage. If the voltage source connected to a voltage grid network is not synchronized with the current range is high. Most systems connected to the network use a Phase-Locked Loop to determine the specific phase angle (θ) of the network voltage (Yun Wei L et al, 2009). Synchronizers, which can be used for three-phase systems are based on synchronous reference system employing Phase locked loop (SFR-PHASE LOCKED LOOP).

The main structure of a (SFR-PHASE LOCKED LOOP) is shown in the figure (4).

**Simulation**

Micro grid consists of a number of sources and several loads. In this study the overall behavior of micro-grids in sync with the main network is reviewed. So the Micro-grid can be modeled with a power source and a load model as shown in Figure (2). As soon as the photos in this sense, micro-grid is isolated from the main network. Synchronization of a generator to the grid, which is placed in the generator motor (receive load from the network) frequency of that component should be lower than the network frequency. Single-Linear schema shown in Figure (5), are simulated with the three phases in MATLAB software. S static key in the this figure has the role of micro-grid synchronization with the main network.

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*Figure 3. Micro-Grid Model For The Separation From Network*
Using equation (1), three-phase PHASE LOCKED LOOP input reference is primarily transferred to synchronous machines or qd0 (Timbus A et al, 2005).

\[ x_{qd0} = T_\theta \cdot x_{abc} \]

In equation (1) \( T_\theta \) is defined as follows:

\[
T_\theta = \frac{2}{3} \begin{bmatrix}
\cos \theta & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\
\sin \theta & \sin(\theta - \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) \\
\frac{1}{2} & \frac{1}{2} & \frac{1}{2}
\end{bmatrix}
\]

Also, input vector is as \( x_{abc} = [x_a \ x_b \ x_c]^T \) and output vector is as \( x_{q0} = [x_q \ x_d \ x_0]^T \). Here it is the input voltage of the system. Thus, in the above relations, for the vector x, vectors V or the input voltage vector is located. Components of Voltage \( V_q \) is inclined to zero by a PI controller. The PI controller output estimates the angular frequency \( (\omega) \) of the synchronous reference PHASE LOCKED LOOP device.

\[ \theta(t) = \theta(0) + \int \omega(t) \, dt \]

According to Equation 3, by integrating the angular frequency, phase angle increases synchronous reference system (\( \theta \)) is obtained. When component \( V_q \) is equal to zero, the \( \theta \) matches the angle of vector of input voltage (Rocabert Joan et al, 2011).

Before synchronization of Micro Grid with main network, first the phase lock loop of two sides of key determines the angle between the main network and the micro grid phases. Figure (2) shows PHASE LOCKED LOOP 1 output which is voltage phase angle of the main network, and the PHASE LOCKED LOOP 2 output which is voltage phase angle of Micro Grid before connecting to the main network.
Figure 6. Phase angle of network

Figure 7. Phase Angle of Micro Grid

Figure (6) shows Micro-Grid phase angle and figure (7) shows the phase angle between main network and the Micro-Grid. If we assume that main network phase angle is fixed, phase angle of Micro Grid slowly becomes closer to main networks. For a Moment they become equal and then it passes the main network’s angle.

When the micro grid’s phase angle matches the phase angle of the main network, micro-grid is synchronized with the main network, and it is the best time to connect micro-grid to the main network. In this mode, the lowest transient mode and the least disruption of current and voltage, will occur. In the simulation, first static key connects the micro-grid to the main network when voltage of micro grid is not synchronized with the main network voltage. As an example, we consider the connection time to 23 seconds, when the micro-grid and main network are not synchronized.

In a asynchronous connection, the phase angle between micro-grid and main network is as shown in figure (8). Instead of the slow adaptation of phase angles, in the connection moment, phase angle are overlapped with a jump. This jump leads to severe fluctuations in current and voltage.

The result of this inaccurate connection is severe disturbance current and voltage. Figures (9) and (10) respectively show the current and voltage of micro-grid connection to the network at the time of asynchronism. As can be seen, in Figure (8) the current range amounts to 1500 amps and even after 5 seconds, the current's fluctuations are not damped.

CONCLUSIONS

MicroGrid must be connected to the main network when the micro grid and main networks voltages are in synchronization. Micro-grid and main network voltage phases are detected using phase lock loop. In the simulation, micro-grid was connected to the main network in the two states of synchronous and asynchronous with the main network. As the simulation indicates when the voltages of micro-grid and main network are synchronized and connection is made, disruption in current and voltage after connection is minimized. If the connection is made when the voltages of micro-grid and main network are not synchronized, disruption in current and voltage after connection is increased drastically. In cases where the phase difference is large, it may lead to micro-grid instability with sharp increase in the current.
Also, since the voltage fluctuations after 23 seconds, the connection are at the wrong time, in the form of (10) is clearly characterized by the fluctuations in voltage. However, when static key micro grid voltage is synchronized with the grid voltage micro-grid is connected to the main network. Duration and amplitude of spontaneous transient network parameters greatly reduced.

In synchronous circuit (phase), the phase angles are a little closer together until they coincide and the phase angles of the compliance (i.e., synchronized to the main network and micro-grid), the connection. This adaptation of the phase angle is shown in figure (11).
In synchronized connection that is synchronization of micro-grid and main network, the voltage and current fluctuations are minimized. Figures (12) and (13) respectively show current and voltage in the synchronous connection. As shown in Figure (12), the range for current fluctuations, reaches a maximum of 90 A, and current fluctuations are damped within 1.9 seconds.

In Figure (13), it is observed that in synchronized connection, the voltage does not even have the slightest fluctuations and voltage changes during and after the connection is completely normal.

REFERENCES


