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Enhancement of reliable power supply in grid associated distributed power generation with renewable sources

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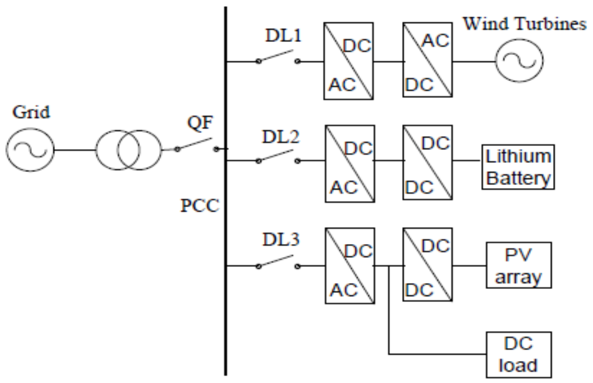
Abstract
Distributed generation (DG) with converter interface to the grid is found in many of the green power resources applications. In this paper the control of voltage source converter (VSC), as the DG front end, is in focus regarding the power quality problems that could appear at the connection point. The aims have been set to maintain a stable operation of the DG in grid connected operation. The paper describes a control strategy that is used to implement constant load current when the load is connecting the renewable energy resources. This paper proposes a constant voltage current control method for a grid connected distributed power generation.
A Simulink based model is developed and the simulation results for the proposed model are obtained by using MAT LAB.

Keywords: distributed generation (DG), constant voltage current control, voltage source converter (VSC)

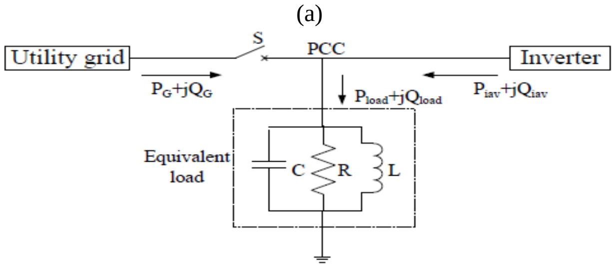
1. Introduction

The consumption of electrical energy is an ever growing need worldwide. Yet, growing in tandem to it are concerns about environmental pollution, global warming and the steady depletion of fossil fuels. Electricity generation from renewable resources might be considered as a feasible solution for the next generations. Traditional power systems implement large power generation plants that produce most of the power, which then is transmitted to large consumption centre's and further distributed between different customers. This power system design structure has, at some locations, started to change towards new scenarios at which distributed generation (DG) units are spread throughout the distribution network, as shown in Fig. 1 for two possible locations. These DGs utilize renewable resources such as wind turbines, photovoltaics, biomass, small hydro-turbines … etc. Beside their environmental benefits, DGs offer a low-cost way for the energy flow into the market since they do not imply substantial transmission losses due to their location near to the customers. Moreover, they could present a reliable and uninterruptible source for the customers especially in rural areas and micro grids. In addition, a possibility where the DG could be beneficial is if it could help to supply load during contingencies until the utility can build up additional delivery capacity. The recent trends in small scale power generation using with the increased concerns on environment and cost of energy, the power industry is experiencing fundamental changes with more renewable energy sources (RESs) or micro sources such as photovoltaic cells, small wind turbines, and microturbines being integrated into the power grid in the form of distributed generation (DG). These RES-based DG systems are normally interfaced to the grid through power electronics and energy storage systems [1] One of the most critical sections of the control system for a distributed generation (DG) unit's interconnection to the utility grid lies within the grid-connected converter's control and protection system;

Islanding is a condition in which a microgrid or a portion of the power grid, which contains both load and distributed generation (DG), is isolated from the remainder of the utility system and continues to operate; Intentional islanding refers to the formation of islands of predetermined or variable extension; these islands have to be supplied from suitable sources able to guarantee acceptable voltage support and frequency, controllability and quality of the supply, and may play a significant role in assisting the service restoration process.



(a)



(b)

Fig 1: (a) Grid interconnected power system (left) and penetration of distributed generation (right). **(b).** Grid islanding from the DG system.

Microgrids, seen as particular types of intentional islands, basically operated in autonomous mode, not connected to the supply system; the whole microgrid can be seen from the distribution system as a single load has to be designed to satisfy the local reliability requirements , in addition to other technical characteristics concerning frequency, voltage control and quality of supply [2]. This paper describes a control strategy that is used to implement grid connected and intentional-islanding operations of micro grids with constant load current.

2. Controller

2.1 Introduction

This system consists of the main source that is represented by the dc source, the conversion unit which performs the interface function between the dc bus and the three-phase ac world, and the *LCL* filter that transports and distributes the energy to the end use and the load [3, 4]. The controller presented provides a constant DG output and maintains the voltage at the point of common coupling (PCC) before and after the grid is disconnected. Under normal operation, each DG system in the main grid usually works in a constant current control mode in order to provide a preset power to the main grid. When the faulty condition or micro grid is cut off from the main grid, each DG inverter system must detect this situation and must switch to a voltage control mode. In this mode, the micro grid will provide a constant voltage to the local load.

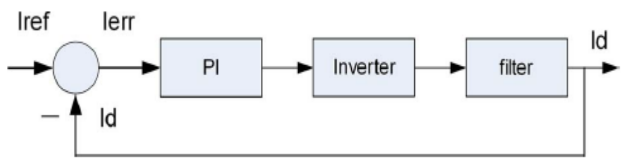


Fig 2: Block diagram of the current controller

When using current control, the output current from the filter, which has been transformed into a synchronous frame by Park's transformation (1) and regulated in dc quantity, is fed back and compared with the reference currents *I*DQref. This generates a current error that is passed to the current regulator (PI controller) to generate the voltage references for the inverter. In order to get a good dynamic response, *V*DQ is fed forward. This is done because the terminal voltage of the inverter is treated as a disturbance, and the feed forward is used to compensate for it. The voltage references in dc quantities *V*DQref are transformed into a stationary frame by the inverse of Park's transformation (2) and are utilized as command voltages in generating high-frequency pulse width-modulated voltages

$$\begin{bmatrix} X_D \\ X_Q \\ X_0 \end{bmatrix} = \frac{2}{3}\begin{bmatrix} -\cos\theta & -\cos(\theta+2\pi/3) & -\cos(\theta-2\pi/3) \\ \sin\theta & \sin(\theta+2\pi/3) & \sin(\theta-2\pi/3) \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \times \begin{bmatrix} X_a \\ X_b \\ X_c \end{bmatrix} \quad (1)$$

Where $\theta = \omega t$ and ω is the frequency of the electric system

$$\begin{bmatrix} X_a \\ X_b \\ X_b \end{bmatrix} = \begin{bmatrix} -\cos\theta & \sin\theta & 1/2 \\ -\cos(\theta-2\pi/3) & \sin(\theta-2\pi/3) & 1/2 \\ -\cos(\theta+2\pi/3) & \sin(\theta+2\pi/3) & 1/2 \end{bmatrix} \begin{bmatrix} X_D \\ X_Q \\ X_0 \end{bmatrix} \quad (2)$$

2.2 Loss of Main Detection

The instant at which the faulty condition or micro grid is cut off from the main grid (intentional-islanding operation) must be detected in order for the DG system to change between grid-connected and intentional-islanding modes.. This detection is achieved by using a DQ-PLL which consists of the Clarke's transformation, the Park's transformation, a PI regulator, and an integrator. The schematic of the DQ-PLL is shown in Fig. 4

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \begin{bmatrix} 2/3 & 1/3 \\ 0 & 1/\sqrt{3} \end{bmatrix} \begin{bmatrix} V_{ab} \\ V_{bc} \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} V_D \\ V_Q \end{bmatrix} = \begin{bmatrix} -\cos\theta & \sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} \quad (4)$$

The lock is realized by setting *Vq* to zero. A PI regulator can be used to control this variable, and the output of this regulator is the grid frequency. In addition to the frequency, the DQ-PLL is capable of tracking the magnitude of its input signals, e.g., the grid voltages [9]. These two parameters, namely, frequency and voltage magnitude, are used in the islanding detection algorithm to detect the grid condition. Then, the algorithm sends a signal that switches the inverter to the suitable interface control. The algorithm is shown in Fig. 3.

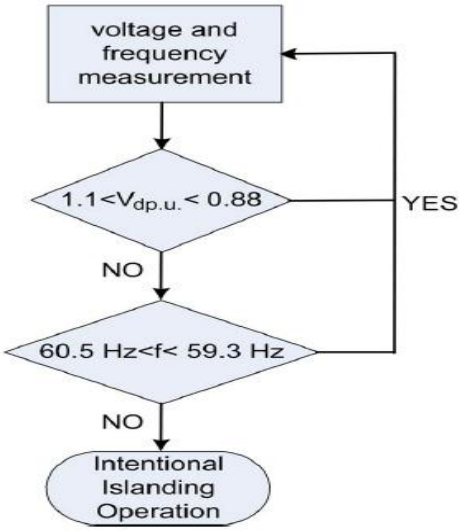


Fig 3: Intentional-islanding-detection algorithm

While serving as good indications for islanding detection, the quick voltage and frequency variations lead to a serious concern: the DG would operate out of the allowable voltage or frequency range quickly after islanding occurs. To avoid this, intelligent load-shedding algorithms need to be implemented in a DG system to make sure that the demand is within available generation by disconnecting some least important loads.

2.3 Intentional-Islanding Operation Mode

The voltage closed-loop control for intentional-islanding operation is shown in Fig. 4. The control works as voltage regulation through current compensation. The controller uses voltage compensators to generate current references for current regulation. As shown, the load voltages (*VD* and *VQ*) are forced to track its reference by using a PI compensator (voltage regulator). The outputs of this compensator (*I*Dref and *I*Qref) are compared with the load current (*ID* and *IQ*), and the error is fed to a current regulator (PI controller).

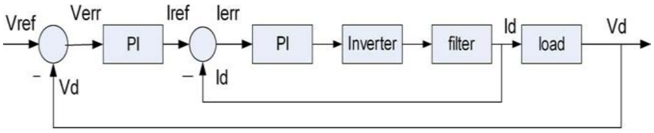


Fig 4: Block diagram of the voltage current-controlled inverter

Current Control Transfer Function

Fig. 2 shows the block diagram of the DG interface control for the grid-connected operation. The PI controller produces a signal that is proportional to the time integral of the controller. The transfer function of the PI controller is given by

$$C(s) = k_P + \frac{k_I}{s} \quad (15)$$

Where ***kp*** is the proportional gain and ***kI*** is the integral gain. The inverter stage does not have any significant transient time associated with it, and hence, it is modeled as an ideal gain.

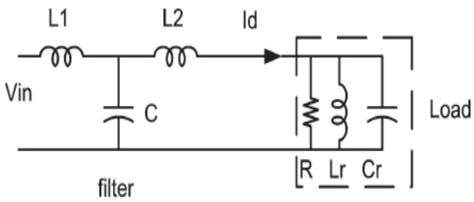


Fig 5: LCL filter and load.

This ideal gain can be given by *GI* (*s*) = 1. The schematic circuit of the filter stage is shown in Fig.5.consists of an *LCL* filter and load. The transfer function of this stage can be expressed as

$$\frac{I_d}{V_{\text{in}}} = \frac{\frac{1}{sC}}{\left(\frac{1}{sC} + sL_2 + R//sL_r//\frac{1}{sC_r}\right) \cdot Z_{\text{total}}} \quad (5)$$

Where

$$Z_{\text{total}} = sL_1 + \frac{1}{sC}//\left(sL_2 + R//sL_r//\frac{1}{sC_r}\right) \quad (6)$$

3. Matlab/Simulink Modeling & Simulation Results

The performance of the proposed control strategies was evaluated by computer simulation using Matlab/Simulink Platform. Here simulation is carried out in different cases; proposed system would be in voltage control technique as well as current controlled technique.

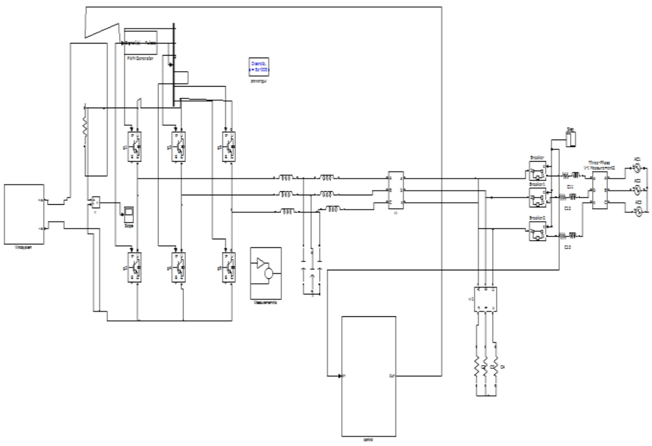


Fig 6: Matlab/Simulink Model of proposed Grid Connected Distribution Generation Interfacing using DG system

Fig. 6 shows the Matlab/Simulink Model of proposed Grid Connected Distribution Generation Interfacing using RES system using Matlab/Simulink Platform.

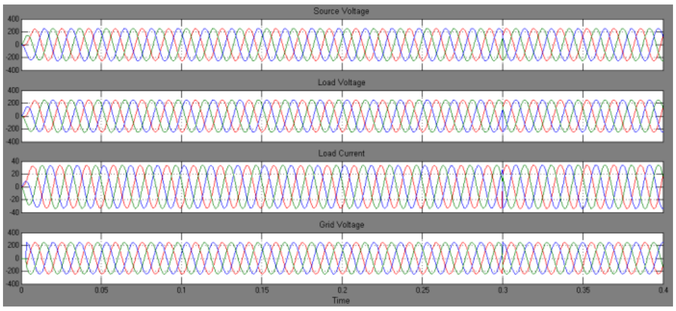


Fig 7: Source Voltage, Load Voltage, Load Current, Grid Voltage

Fig.7. shows the Source Voltage, Load Voltage, Load Current, and Grid Voltage of proposed Grid Connected Distribution Generation Interfacing using DG system under voltage control mode.

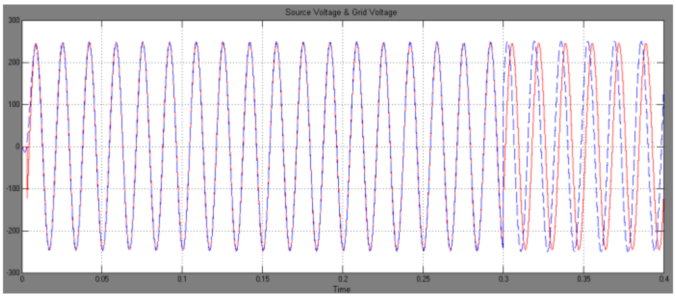


Fig 8: Synchronization of Source Voltage & Grid Voltage

Fig. 8 shows the Synchronization of Source Voltage & Grid Voltage of proposed Grid Connected Distribution Generation Interfacing using DG system under voltage control mode.

4. Conclusion

A voltage & current controller was designed with interfacing control techniques one for grid-connected operation and the other for intentional islanding operation or for faulty conditions. An islanding-detection algorithm, which was responsible for the switch between the two controllers, was presented. The simulation results showed that the detection algorithm can distinguish between islanding events and changes in the loads and can apply the load-shedding algorithms when needed. In addition, it is shown that the response of the proposed control schemes is capable of maintaining the voltages and currents within permissible levels during grid connected and islanding operation modes. The simulation results showed that the proposed control schemes are capable of maintaining the voltages and currents within the standard permissible levels during grid-connected and faulty or islanding operation modes.

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