International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 10, October-2015

Control Scheme for Islanded Operation of Distributed Energy Resource

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***Abstract*—The islanded operation of distributed energy resource has gained importance due to increase in demand of power. But islanded operation of distributed energy resource faces certain problems. The islanded operation cannot maintain the voltage at a stable value. Hence a control scheme is introduced so as to obtain a stable voltage at islanded condition. The system is simulated in MATLAB/SIMULINK platform.**

Keywords—Renewable Energy Resources; Distributed Energy Resources; Islanded Operation; Microgrids;

I. Introduction

The concept of islanded operation of Distributed Generation (DG) systems (collectively referred to as Distributed Energy Resource (DER) systems) has gained interests under the umbrella of microgrids [1]. Islanded operation mainly enhances the system reliability. Islanded operation can be effectively utilized for electrification of remote communities. Islanded operation further provides opportunity to supply electricity and heat from renewable energy resource and hence helps in reduction of use of fossil fuels. Most modern distributed energy resource units generate DC power, or AC power with frequencies different from 50 or 60 Hz. The distributed energy resources connected to the grid often employ a Phase Locked Loop (PLL) [2] to maintain the frequency. In islanded mode the variation in load affects the system. In order to overcome the above problem, a robust control scheme is employed in [3]. In [4] a voltage-mode control strategy has been proposed for an electronically-interfaced distributed energy resource unit. A current-mode control strategy can be seen in [5]. In this paper voltage and current control schemes are employed for the islanded operation. The paper details the mathematical model of an islanded system and the control design methodology. The simulation is carried out in MATLAB/SIMULINK platform.

II. Structure of Islanded Distributed Energy Resource Unit

The islanded structure of a distributed energy resource unit is shown in figure 1[6]. It consists of current-controlled VSC and a three-phase LC filter that supplies the load. L and C_f represent the inductance and capacitance of the filter. R models the ohmic loss of the filter inductor and also includes the effect of the on-state resistance of the VSC valves.

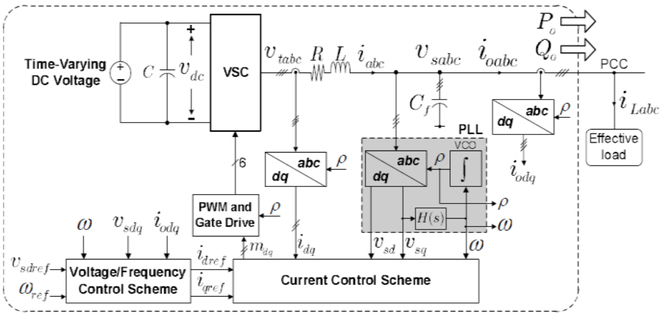

Figure 1: Schematic diagram of distributed energy resource unit

The unit is controlled in a rotating dq reference frame whose d axis makes an angle ρ against the stationary α axis. ρ is obtained from a PLL which constitutes an essential part of a modern electronically-coupled distributed energy resource unit. The PLL also provides ω, i.e. the frequency of v_{sabc}.

III. Mathematical Model of Distributed Energy Resource Unit

The mathematical equations governing the dynamics of load voltage with reference to the figure 1 are given by the equation

$$C_f \frac{d}{dt}\vec{v}_s = \vec{i} - \vec{i_0} \quad (1)$$

The dq-frame equivalent of equation 1 can be obtained as

$$C_f \frac{d}{dt}\left[\left(v_{sd} + jv_{sq}\right)e^{j\rho}\right] = \left(i_d + ji_q\right)e^{j\rho} - \left(i_{od} + ji_{oq}\right)e^{j\rho} \quad (2)$$

where ρ is the dq-frame angle. Equation 2 can be simplified and written as

$$C_f \frac{d}{dt}[v_{sd}] = (C_f\omega)v_{sq} + i_d - i_{od} \quad (3)$$

$$C_f \frac{d}{dt}[v_{sq}] = (C_f\omega)v_{sd} + i_q - i_{oq} \quad (4)$$

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IV. CONTROL SCHEMES

The system described employs two control schemes. The block diagram representation of the control schemes is shown in figure 2.

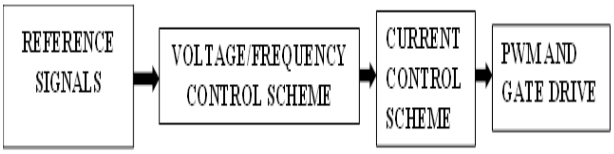


Figure 2: Block diagram of control schemes

The electronic interface of the DER unit employs a current-controlled VSC. The block diagram of the current control scheme is shown in figure3.

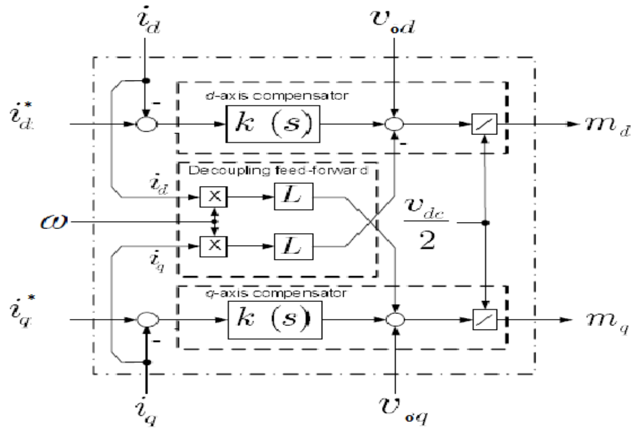


Figure 3: Current control scheme

The d-axis and q-axis current component reference signals are given to a compensator and a decoupling strategy is used to obtain the necessary voltage signals which further provide the control signals. The objective of the current control scheme is to regulate the d-axis and q-axis components of the VSC ac-side current by means of the pulse width modulation (PWM) switching strategy. This is done in order to ensure the regulation of the amplitude and frequency of the DER unit terminal voltage. Thus the current control scheme provides the modulating signals and thus determines the switching instants of the VSC valves.

The voltage/frequency control scheme regulates the d-axis and q-axis components of the Distributed Energy Resource unit terminal voltage at the set points. This scheme processes the error signals and generates the set points for the current control scheme. Figure 4 shows the block diagram of the voltage control scheme.

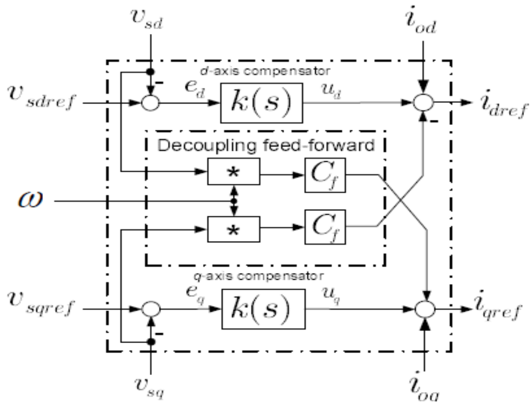


Figure 4: Block diagram of voltage control scheme

V. SIMULATION AND RESULTS

The DER unit is modeled in MATLAB. The power circuit of the DER unit consists of a conditioned prime energy source which is modeled by a DC voltage source, a Voltage-Source Converter (VSC), and a three-phase LC filter. The system is modeled with voltage and current controllers. The current and voltage control schemes are employed to attain the stability of the system. Figure 5 shows the simulink model of the system which is connected to a load with an active power of 1kW.

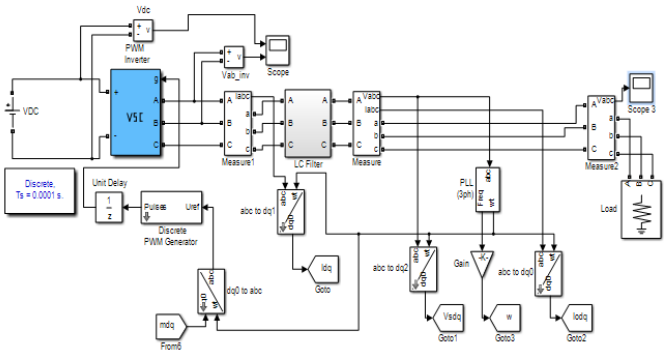
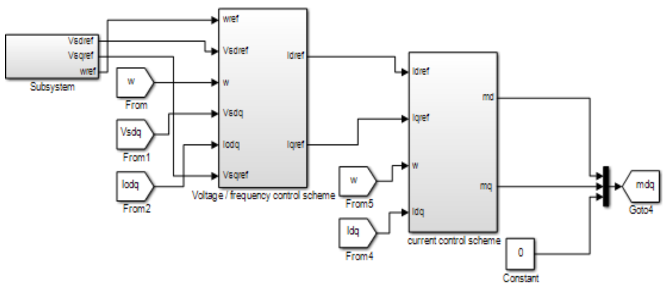


Figure 5: Simulink model of the system

The control schemes are provided to maintain the amplitude of the voltage and the frequency. Two schemes namely, the voltage control scheme and the current control schemes are employed. The control scheme subsystem is shown in figure 6.



. Figure 6: Simulink model of the subsystem

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The control schemes are the voltage and current control schemes. The voltage control scheme provides the reference signals I_{dref} and I_{qref}. The current control scheme provides the reference signal m_{dq}. The reference signal generated is used for the gating control of the voltage source converter.

The model is simulated in the MATLAB/Simulink platform and the waveforms are obtained. Figure 7 shows the DC voltage provided.

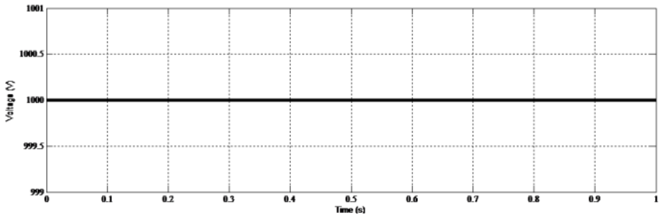

Figure 7: Input voltage waveform

A DC voltage of 1000V is given as the input which can be seen in figure 7. Figure 8 shows the corresponding output produced by the voltage source converter.

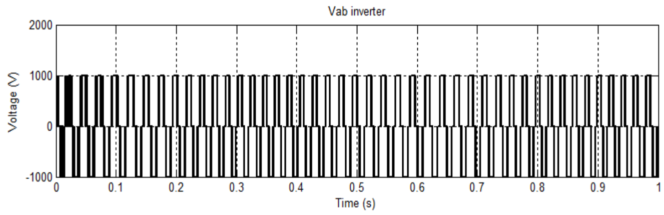

Figure 8: Inverter output voltage waveform

The voltage source converter produces an output of 1000V corresponding to the given input voltage. Figure 9 shows the

The output voltage attains a steady value. The system is connected to a load of 1kW. The corresponding current waveform is shown in figure 10.

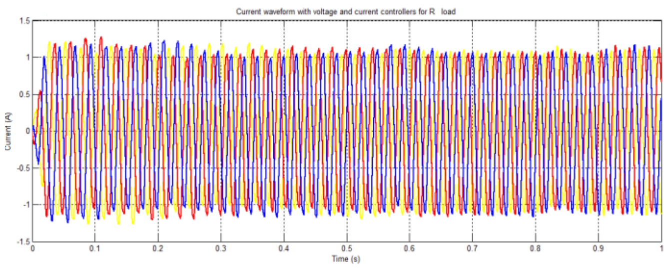

Figure 10: Output current waveform

output voltage waveform when a resistive load is connected to the distributed energy resource unit.

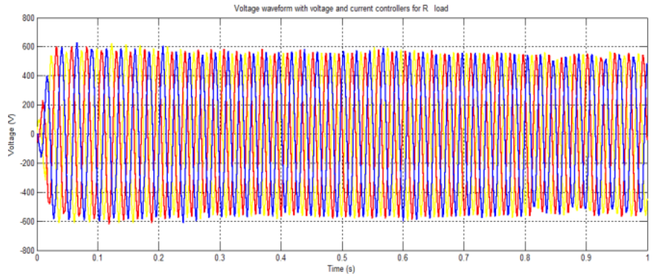

Figure 9: Output voltage waveform

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VI. CONCLUSION

It is evident from the results that the controllers are capable of maintaining the voltage at steady operating range. Thus the islanded operation of the distributed energy resource with voltage and current controllers has improved the system performance.

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