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Voltage Stability with Islanded Distributed Energy Resource Unit

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***Abstract*— The distributed energy resource utilization is increased and their operation in islanded mode has also gained importance. The voltage stability of a system connected to an inductive load is of concern. A voltage and current control scheme is introduced to obtain voltage stability. The system is simulated in MATLAB/SIMULINK platform.**

***Index Terms*— distributed energy resources;; islanded operation; microgrids; renewable energy resources.**

I. INTRODUCTION

The concept of islanded operation of Distributed Energy Resource (DER) systems has gained interests under the umbrella of microgrids [1]. Islanded operation can be effectively utilized for electrification of remote communities. Also, islanded operation enhances the system reliability. Islanded operation helps in reduction of use of fossil fuels. Islanded operation not only provides opportunity to supply electricity but also supplies heat from renewable energy resource. Most modern distributed energy resource units generate 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 and voltage is not stabilized. 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 distributed energy resource unit. A current-mode control strategy is discussed 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. ISLANDED DISTRIBUTED ENERGY RESOURCE UNIT

Figure 1 describes the islanded structure of a distributed energy resource unit [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.

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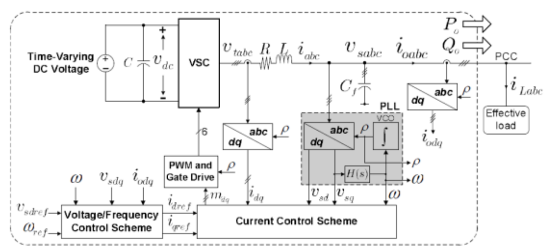


Figure 1: Schematic diagram of distributed energy resource unit

The unit is controlled in a rotating dq reference frame whose d axis makes an angle ρ against the stationary axis. ρ is obtained from a PLL. The PLL also provides ω, i.e. the frequency of v_{sabc}.

III. MATHEMATICAL MODEL OF UNIT

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

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

The dq-frame equivalent of (1) can be obtained as

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

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

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

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

IV.CONTROL SCHEMES

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

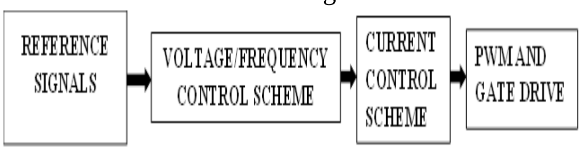


Figure 2: Block diagram of control schemes

The 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 3 shows the block diagram of the voltage control scheme.

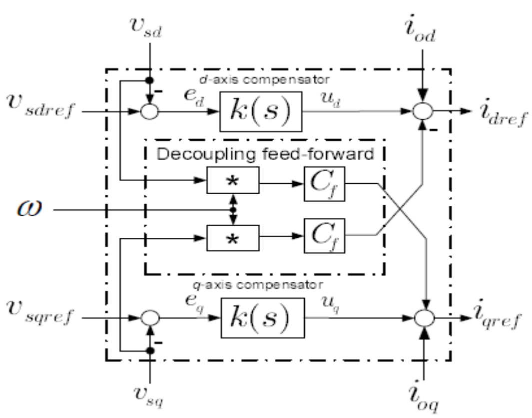


Figure 3: Block diagram of voltage control scheme

The electronic interface of the DER unit employs a current-controlled VSC. The block diagram of the current control scheme is shown in figure4.

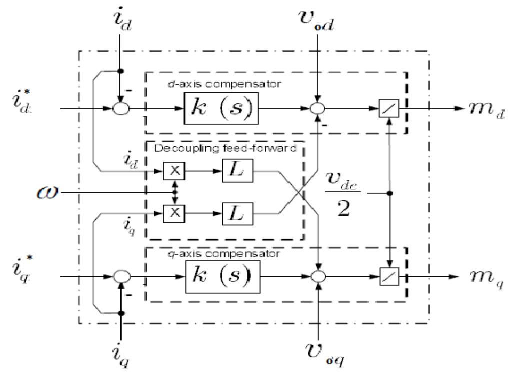


Figure 3: Current control scheme

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 switching instants of the VSC valves.

V. SIMULATION AND RESULTS

The DER unit is modeled in MATLAB. The power circuit of the DER unit consists of 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 and reactive power of 1kVAr.

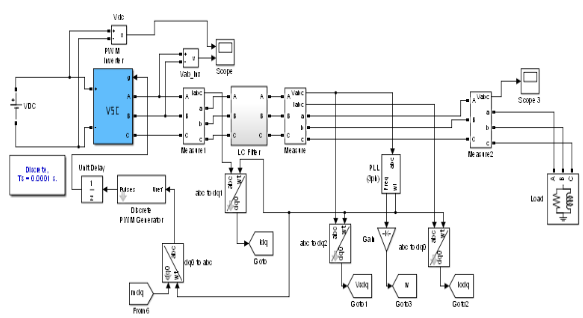


Figure 5: Simulink model of the system

Two schemes namely, the voltage control scheme and the current control schemes are employed to maintain the amplitude of the voltage and the frequency. Figure 6 shows the control scheme subsystem.

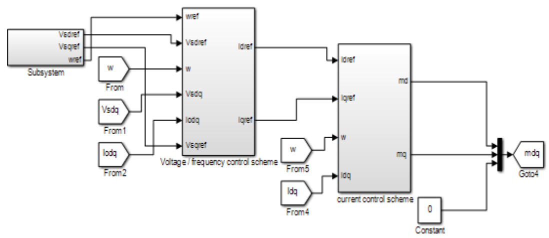


Figure 6: Simulink model of the subsystem

The voltage control scheme provides the reference signals I_{dref} and I_{qref}. The current control scheme provides the reference signal m_{dq}.

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

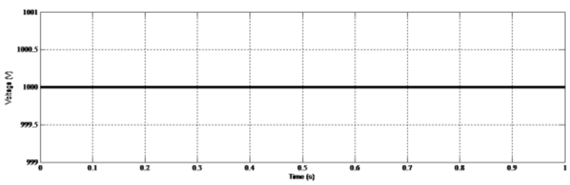


Figure 7: Input voltage waveform

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.

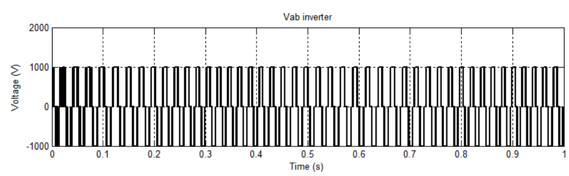


Figure 8: Inverter output voltage waveform

The voltage source converter produces an output of 1000V corresponding to the given input voltage. Figure 9 shows the output voltage waveform when an inductive load is connected to the distributed energy resource unit.

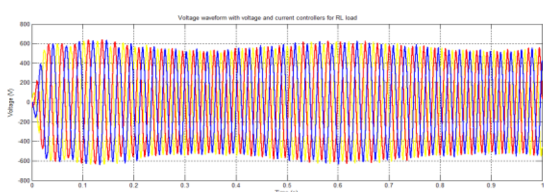
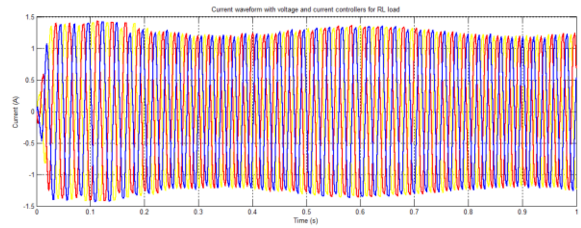


Figure 9: Output voltage waveform

The system is connected to a load with active power of 1kVA and reactive power of 1kVAr. The corresponding current waveform is shown in fig.10.



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 when an inductive load is connected to the system.

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