Parallel Operation of Virtual Synchronous Generators in a Microgrid

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1. Introduction

A New Concept of Inverter Control in AC Microgrid

Conventional Droop Control + Swing Equation Imitation → Virtual Synchronous Generator (VSG) Control

Issues to Solve
1. Active power oscillation during a disturbance
2. Inappropriate transient load active power sharing
3. Sharing errors in reactive power

2. Basic VSG Control

\[ P_{in} - P_{out} = f \omega_m \frac{d \omega_m}{dt} + D (\omega_m - \omega_g) \]

V-Q Droop

\[ K_v, \text{ V-Q Droop Coefficient} \]

\[ Q, \text{ Set Value of Reactive Power} \]

Distributed Generator

Energy Storage

VSG Control

Swing Equation

\( J \): Moment of Inertia

\( D \): Damping Factor

\( \omega \): Angular Frequency

\( \omega_m \): Angle of VSG

\( L_f \): Line Impedance

\( Z_{line} \): Line Impedance

\( R_Z \): Load Sharing

\( \omega_i \): Angular Frequency

3. Problem Analysis

Studied Microgrid in islanded mode

DG: Inverter-based Distributed Generator equipped with VSG control

Active Power Oscillation

Transmit Load Sharing

Eigenvalues of State Matrix

Poles and Zeroes of \( \Delta_{part, \Delta_{prop}} \)

Damping ratio (indicated by the radial dash lines) can be increased by increasing output reactance

Oscillation being damped owing to increased output reactance

4. Proposed VSG Control

Using local voltage and current to estimate bus voltage for proper reactive power sharing

Using virtual impedance control to increase output reactance of each DG to a same large per unit value

5. Experimental Results

Oscillation being damped owing to increased output reactance

Basic VSG Control

Proposed VSG Control

For proper reactive power sharing, voltage used for V-Q Droop of each DG should be equivalent

6. Conclusion

1. Virtual impedance control was proposed to increase output reactance and to adjust output reactance mismatch, in order to increase system damping and to properly share transmit load

2. Bus voltage estimator was proposed to provide a common reference for the V-Q droop, in order to properly share reactive power

3. The effects of both virtual impedance control and bus voltage estimator were proved by experimental results