Three-Phase Grid-Tied Inverter with SRF-PLL Control

This Simulink model implements a Three-Phase Voltage Source Inverter (VSI) tied to a grid/load, utilizing Synchronous Reference Frame (SRF) theory for high-performance current control and grid synchronization.

System Architecture

The model is divided into two primary sections: the Power Stage (top) and the Control Strategy (bottom).

1. Power Stage

- DC Source: A constant DC voltage input.
- Three-Phase Inverter: A universal bridge controlled by six PWM signals.
- LCL Filter: Inductive-Capacitive-Inductive filtering to suppress high-frequency switching harmonics before reaching the grid.
- Three-Phase Load/Grid: Represented by the AC voltage source and impedance blocks on the far right.
- Measurements: Voltage (V_{abc}) and current (I_{abc})sensors provide feedback to the control loops via Go-To/From tags.

2. Control Strategy (Lower Section)

The control logic is implemented in the dq rotating reference frame to simplify the AC signals into DC-like quantities.

- Synchronous Reference Frame PLL (SRF-PLL): * Uses Clarke (α/β) and Park (dq) transformations on the grid voltage.
  - A PI controller forces the q-axis voltage to zero, effectively locking the phase angle (Φ) to the grid.
- Current Control Loop:
  - Inner Loop: Separate PI controllers for I_d (active power/current) and I_q (reactive power/current).

- Decoupling/Feedforward: Includes cross-coupling terms and grid voltage feedforward to improve dynamic response.

- PWM Generation: * The resulting control signals are transformed back to the abc frame.
  - A PWM generator converts these signals into the 6 switching pulses (PWM1 through PWM6) for the inverter IGBTs.

Key Components & Parameters

Component	Description
PowerGui	Set to Discrete mode with a sample time of $1*10^{-6}$
Clarke/Park Transformation	Convert abc to $\alpha\beta$ to dq
PI Controllers	Regulate I_d, I_q and the PLL phase error.
Scope	Monitors real-time output voltage and current for stability analysis.

How to Use

1. Initialization: Ensure the powergui block is present and set to the desired simulation type (Discrete is recommended for power electronics).
2. Configuration: * Open the PI controller blocks to tune the Proportional (K_p) and Integral (K_i) gains.
   - Set the DC link voltage and grid voltage/frequency to match your specific application.
3. Simulation: * Run the simulation.
   - Open the Scope to observe the sinusoidal output current and its alignment with the grid voltage.
   - Verify that the dq currents track their reference values (1 for I_d and 200 for I_q in the current configuration).

Expected Results

Upon a successful run, the inverter should demonstrate:

- Synchronization: The PLL should converge quickly, providing a stable ωt signal.
- Current Tracking: The measured I_d and I_q should reach their respective setpoints with minimal steady-state error.
- Low THD: The LCL filter should ensure the output current waveforms are smooth sinusoids.