

Active Front End (AFE) Rectifier Simulink Model

This repository contains a **MATLAB/Simulink** implementation of a three-phase **Active Front End (AFE) Rectifier**. Unlike passive diode bridges, this AFE uses controlled switches (IGBTs/MOSFETs) to provide bi-directional power flow, low harmonic distortion (THD), and unity power factor operation.

Overview

The model simulates a grid-connected voltage source converter (VSC) acting as a rectifier to maintain a constant DC bus voltage while ensuring sinusoidal grid currents.

Key Features

- **Vector Control (dq-frame):** Decoupled control of real and reactive power.
- **Inner Current Loop:** Fast-acting PI controllers for I_d and I_q current components.
- **Outer Voltage Loop:** Maintains the DC bus at a reference value (set to 800V in this model).
- **Phase-Locked Loop (PLL):** Accurate grid synchronization using an alpha-beta to dq transformation.
- **LCL Filter:** High-frequency harmonic attenuation between the converter and the grid.
- **PWM Generation:** Sine-PWM modulation for driving the 6-pulse converter bridge.

Control Strategy

The control architecture is divided into several functional blocks:

1. **Grid Synchronization (PLL):** Extracts the phase angle (ωt) from the grid voltage to facilitate $abc \rightarrow dq$ transformations.
2. **Transformation Blocks:**
 - **Clarke/Park Transformation:** Converts 3-phase stationary signals to 2-phase rotating signals (V_d , V_q and I_d , I_q).
3. **DC Voltage Regulation:** The outer loop compares the measured V_{DC} against the 800V reference, generating the I_d reference for active power.
4. **Current Decoupling:**

Cross-coupling terms (using the $-K$ gain blocks) and feed-forward grid voltages are added to the current controller outputs to improve dynamic response.

Model Components

Component	Description
Power Stage	3-phase AC source, LCL Filter, and Universal Bridge.
Sensors	Voltage and Current measurements for grid (V_{abc} , I_{abc}) and DC Link (V_{DC}).
Control Logic	Discrete-time PI controllers for voltage and current loops.
Modulator	PWM generator converting V_{ref} signals into gate pulses (PWM1-PWM6).

Getting Started

Prerequisites

- MATLAB (R2021a or newer recommended)
- Simulink
- Simscape Electrical (Specialized Power Systems)

Results

Expected performance includes:

- DC Voltage:** Rapid tracking of the 800V setpoint with minimal overshoot.
- Power Factor:** Grid current I_{abc} should be in phase with grid voltage V_{abc} (Unity Power Factor).
- THD:** Low total harmonic distortion due to the LCL filter and high-frequency switching.