

## 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 ( $\omega_t$ ) 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).

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## 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.