PFC Totem-Pole Converter Control Strategy

Mohamed Gueni

August 31, 2024

Contents

1 Introduction

This document outlines the control strategy for a PFC Totem-Pole Converter with 3 legs, where each leg contains MOSFETs. The converter has an AC input and provides a 400V DC output. A coupled choke is placed on the line to improve the performance of the power factor correction.

2 Control Strategy Overview

2.1 Purpose

To regulate the output voltage, maintain high power factor, and ensure efficient operation of the PFC Totem-Pole Converter.

2.2 Key Control Blocks

The control strategy includes the following key blocks:

- Voltage Regulation
- Power Factor Correction (PFC)
- Current Limiting
- Soft-Start
- Temperature Monitoring

3 Voltage Regulation

3.1 Purpose

To maintain the desired DC output voltage of 400V despite variations in input voltage and load conditions.

3.2 Implementation

- **PI or PID Controller:** A Proportional-Integral (PI) or Proportional-Integral-Derivative (PID) controller processes the error between the actual output voltage and the reference voltage.
- **Feedback Loop:** Measures the output voltage and adjusts the duty cycle of the MOSFETs to maintain the output at 400V.

3.3 Controller

The output of the voltage regulation loop controls the duty cycle of the MOSFETs in the PFC circuit.

3.4 Detailed Implementation

- **Objective:** Ensure that the DC output voltage is regulated to 400V by adjusting the duty cycle of the MOSFETs.
- **Components Needed in PLECS:**
  - **PI or PID Controller:**
    * Processes the error between the measured output voltage and the reference voltage.
  - **Voltage Feedback:**
    * Measures the output voltage and provides feedback to the controller.
- **Block Diagram in PLECS:**
  - **Input:** Error signal from the output voltage regulation loop.
  - **Processing:** Use a PI or PID controller to process the error signal and adjust the MOSFET duty cycle.
  - **Output:** Control signals for the MOSFETs to maintain the desired output voltage.
- **Implementation Steps in PLECS:**
  1. **Create a PI or PID Controller block** that takes the voltage error signal as input.
  2. **Link the output of the Voltage Feedback** to the input of the PI or PID Controller.
  3. **Generate gate drive signals** for the MOSFETs based on the controller output.

4 Power Factor Correction (PFC)

4.1 Purpose

To correct the power factor by ensuring that the current drawn from the AC source is in phase with the input voltage, thus improving the efficiency of the converter.

4.2 Implementation

- **Current Feedback:** Measures the input current and provides feedback for phase and amplitude correction.
- **Control Algorithm:** Adjusts the duty cycle of the MOSFETs to correct the phase angle between the voltage and current.

4.3 Controller

A control algorithm such as a sliding mode controller or another advanced PFC technique can be used to ensure proper power factor correction.

4.4 Detailed Implementation

- **Objective:** Achieve a power factor close to unity by adjusting the duty cycle of the MOSFETs in response to current and voltage feedback.
- **Components Needed in PLECS:**
  - **Current Sensor:**
    * Measures the input current and provides feedback.
  - **Control Algorithm Block:**
    * Adjusts the duty cycle of the MOSFETs based on current and voltage feedback.
- **Block Diagram in PLECS:**
  - **Input:** Current feedback and voltage measurements.
  - **Processing:** Use the control algorithm to process the feedback and adjust the duty cycle.
  - **Output:** Control signals for the MOSFETs to correct the power factor.
- **Implementation Steps in PLECS:**
  1. **Create a Current Sensor block** to measure the input current.
  2. **Implement the Control Algorithm** to process current and voltage feedback.
  3. **Generate gate drive signals** for the MOSFETs based on the control algorithm output.

5 Current Limiting

5.1 Purpose

To protect the converter from excessive current that could damage components.

5.2 Implementation

- **Current Limiting Circuit:** Monitors the current and limits it to safe levels by adjusting the duty cycle of the MOSFETs or shutting down the converter.

5.3 Controller

Current protection logic integrated with the control loop or as a separate protection circuit.

5.4 Detailed Implementation

- **Objective:** Prevent damage by limiting the current to safe levels.
- **Components Needed in PLECS:**
  - **Current Sensor:**
    * Measures the current and provides feedback to the limiting circuit.
  - **Current Limiting Block:**
    * Adjusts the duty cycle or shuts down the converter based on current feedback.
- **Block Diagram in PLECS:**
  - **Input:** Current measurement feedback.
  - **Processing:** Use the current limiting block to process feedback and adjust the duty cycle or shut down.
  - **Output:** Adjusted control signals or shutdown command.
- **Implementation Steps in PLECS:**
  1. **Create a Current Sensor block** to measure the input current.
  2. **Implement the Current Limiting Block** to process the current feedback.
  3. **Generate control signals** based on the limiting block's output.

6 Soft-Start

6.1 Purpose

To gradually ramp up the output voltage and current to prevent inrush currents and ensure smooth startup.

6.2 Implementation

- **Soft-Start Circuit:** Gradually increases the duty cycle or switching frequency from a low value to the normal operating point during startup.

6.3 Controller

Typically integrated with the voltage regulation loop, where the reference voltage or duty cycle is gradually ramped up.

6.4 Detailed Implementation

- **Objective:** Smoothly ramp up the operation of the converter to avoid inrush currents.
- **Components Needed in PLECS:**
  - **Soft-Start Block:**
    - Gradually increases the duty cycle or frequency during startup.
- **Block Diagram in PLECS:**
  - **Input:** Soft-start control signal.
  - **Processing:** Ramp up the duty cycle or frequency.
  - **Output:** Gradually increased control signals for the MOSFETs.
- **Implementation Steps in PLECS:**
  1. **Create a Soft-Start Block** that controls the ramp-up of the duty cycle or frequency.
  2. **Link the Soft-Start Block** to the control signals for the MOSFETs.

7 Temperature Monitoring and Protection

7.1 Purpose

To protect the MOSFETs and other critical components from overheating.

7.2 Implementation

- **Thermal Sensors:** Measure the temperature of the MOSFETs and other critical components.
- **Thermal Protection Logic:** Reduces the duty cycle, shuts down the converter, or engages cooling mechanisms if temperatures exceed safe limits.

7.3 Controller

Thermal protection circuit integrated with the main control loop or as a separate module.

7.4 Detailed Implementation

- **Objective:** Ensure safe operation by monitoring and managing temperatures.
- **Components Needed in PLECS:**
  - **Temperature Sensors:**
    * Measure temperatures and provide feedback.
  - **Thermal Protection Block:**
    * Adjusts the operation based on temperature feedback.
- **Block Diagram in PLECS:**
  - **Input:** Temperature feedback.
  - **Processing:** Use thermal protection logic to adjust operation or shut down.
  - **Output:** Adjusted control signals or shutdown command.
- **Implementation Steps in PLECS:**
  1. **Create Temperature Sensors** to monitor critical components.
  2. **Implement Thermal Protection Logic** based on sensor feedback.
  3. **Generate control signals** or shutdown commands based on the protection logic.