AC Power Factor Correction

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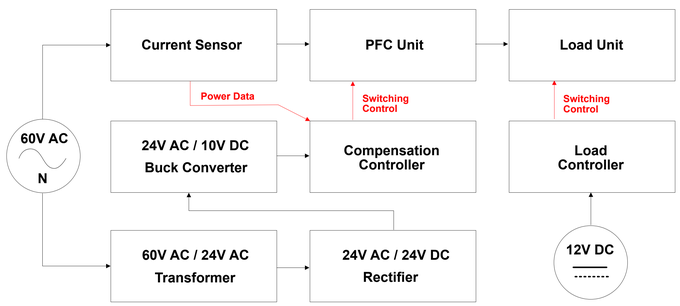
Abstract

This project produced a model automatic power factor correction system for a variable inductive AC load supplied at 60 V RMS, 60 Hz. The system uses microcontrollers to control a switched capacitor and inductor bank. A microcontroller monitors reactive power on the bus. Solid state relays connect capacitors and inductors to the AC bus with electrical isolation from the control system. A DC power supply including a step-down transformer, bridge rectifier, and buck converter supplies the compensation microcontroller. A discrete control scheme controls the solid state relays.

Overview

Power Flow Diagram

Power factor (PF) is the ratio of real power absorbed by a load to the apparent power absorbed by a load. A low power factor occurs when a load consumes or generates reactive power. It is caused by non-linear components that store and release power in an AC system. For ideal transfer of power from a source to a load, power factor should be 1. A low power factor load requires more transmission capacity in VA than is necessary for it to function.



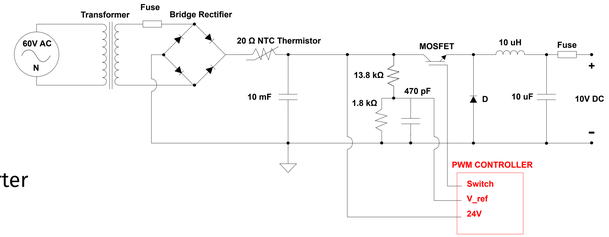
PFC System Block Diagram

This system monitors the reactive power supplied to the series connection of compensation and load units. It controls the reactive power injected by the compensation unit based on that data.

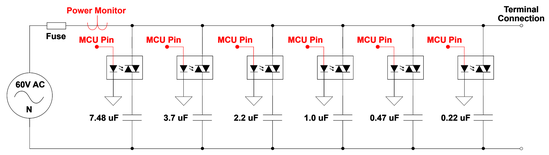
Design

The injection of reactive power is accomplished by connecting X2 rated safety capacitors to the AC bus that carries power through the PFC unit and to the load. DC power is supplied to the the microcontroller that monitors and controls the PFC using a rectifier and buck converter.

- DC system is isolated from AC power bus
- NTC Thermistor reduces inrush current
- Closed loop DC-DC buck converter with controller IC



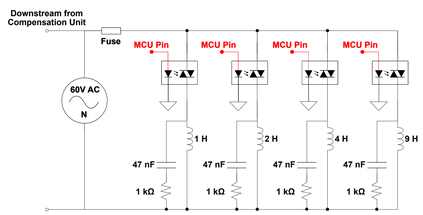
DC Power Supply Circuit Diagram



PFC Unit Circuit Diagram

- Solid state relays isolate MCU from AC power bus
- Binary-weighted bank of capacitors injects programmable reactive power with step size of 0.278 VAR (0.22uF)
- Solid state relays are driven by 5V digital output from MCU

- Programmable test load setup is similar to PFC Unit
- Snubber circuits suppress voltage spike caused by inductor switching
- Load must be downstream of PFC for reactive power monitoring

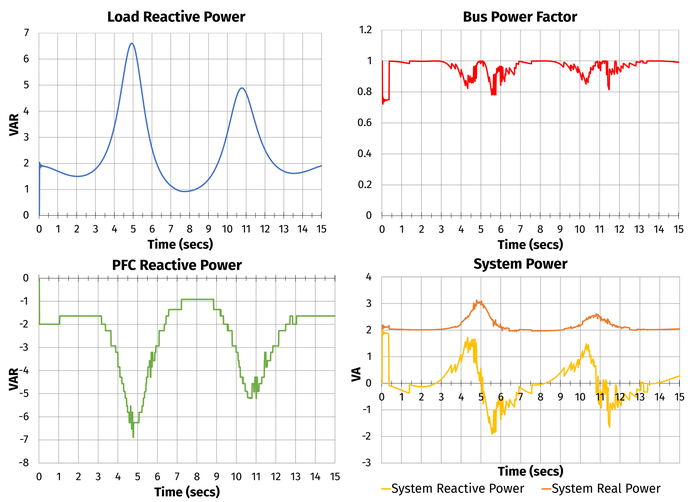


Load Unit Circuit Diagram

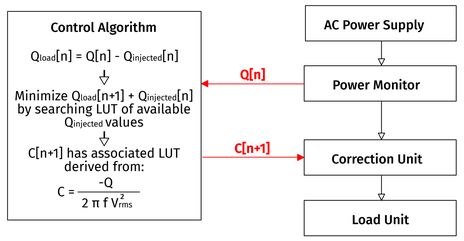
Simulation

The PFC system was simulated in Simulink with the discrete capacitor bank and control, supplying a continuously variable reactive load.

- 15 Sec run time
- 50 µSec sample time
- 60 Vrms 60Hz AC Power
- 1.8 Watt Resistive Load
- Continuously Variable Reactive Load
- Algebraic Control



PFC Simulation Results



Control System Diagram

Results

Power Monitoring:

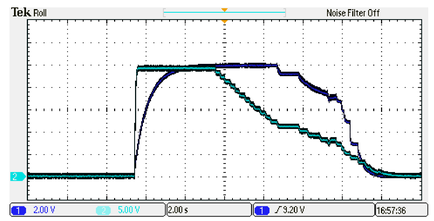
- Voltage measurement within 7% accuracy
- Current measurement too coarse at ±20mA resolution
- Power measurements compromised by poor current resolution

PFC Unit:

- Reactive power output sweep from -0.278 to -20 VAR with -0.278 step size
- Control is limited by Power Monitor accuracy

Buck Converter:

- Stable power supply to MCU under 24-12V input
- Maximum output current of 1 A



Buck Converter Input and Output with MCU Load

Rectifier Stage:

- Significant voltage drop from AC to DC output

Future Work

Power Monitor:

- Implement unit with finer current resolution

DC Power Supply:

- Improve supply efficiency by reducing voltage drop across system

System Integration:

- Integrate inductor bank to PFC unit and adjust control system to compensate capacitive and inductive loads