Single Phase Variable Frequency Switch Gear

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Introduction

Overview

Variable frequency drives vary the speed of alternating current (AC) induction motors by varying the frequency and voltage supplied to the motor.

Objective

To design, build, and test single phase variable frequency switch gear that accepts a user selected input frequency between 1 and 60 Hz to generate an output voltage with a constant Volts/Hertz ratio.

Significance

Variable frequency drives provide energy efficiency benefits to industries that consume large amounts of power operating AC machines. Successful design of single phase variable frequency switch gear can be extended to three phases, which would pave the way for the design of a variable frequency drive.

Design Approach

Design of single-phase variable frequency switch gear was accomplished through the design of three subsystems. The subsystems are a pulse-width modulation (PWM) generation controller, gate drive circuitry, and a DC-to-AC voltage inverter. The variable frequency switch gear must provide output frequencies in the range of 1-60 Hz, must use switching devices rate for a current of 1.5 A_{RMS}, must have a grounded neutral, and must be safe.

References

[1] *Introduction to AC Drives*, [Online]. Available: http://vl.graybar.com/automation/ga_manuals/Drives/ALT%2018 /ITACDS-D.PDF
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[4] K. Lemke and M. Pasternak, "Variable Frequency AC Source (VFACS) Project Report," Bradley Univ., Peoria, IL, 2014.
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Method of Solution

Subsystem Block Diagram

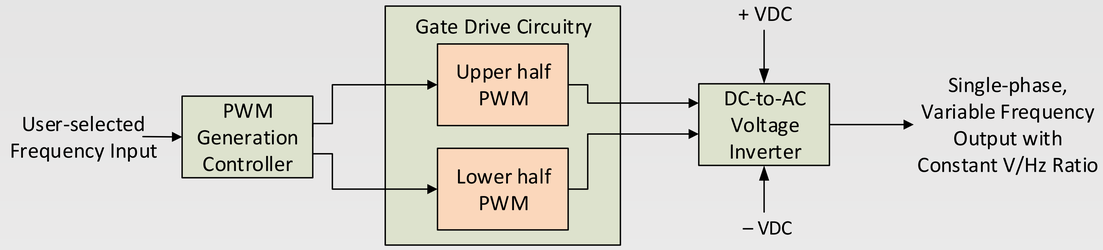

Fig. 1. Subsystem block diagram for single-phase variable frequency switch gear.

PWM Generation Controller

The PWM Generation Controller involves comparing two waves within a program and the result of the comparison is the output for the PWM. A triangle wave with a constant 3 kHz frequency and a fully rectified sine wave with a user selected frequency input between 1 and 60 Hz in whole number intervals are being compared.

The PWM signal is output on alternating bits in order to control the power transistor gate driver on the positive and negative half cycles. There is a 1 µs delay between each of the half cycles to ensure the power transistors are not on simultaneously.

The result is a PWM signal with varying duty cycles that is representative of a fully rectified sine wave.

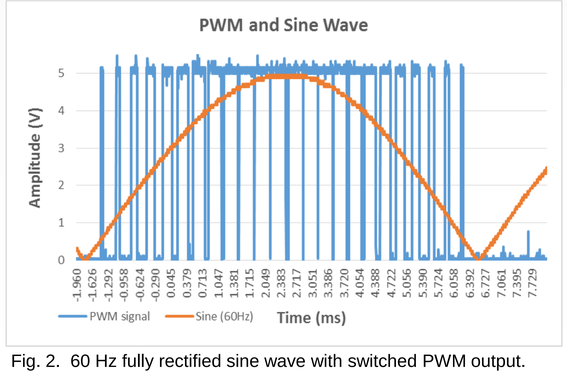

Fig. 2. 60 Hz fully rectified sine wave with switched PWM output.

Gate Drive Circuitry

Gate drive circuity consists of two 8-pin Avago HCPL-3120 chips that are used to amplify voltages and currents to a usable level for the power transistors in the DC-to-AC voltage inverter. One HCPL-3120 chip is used for a high side driver while the other is used for a low side driver. The Avago HCPL-3120 is an optical isolator which will protect the microcontroller used in the PWM generation controller from high voltages and currents used in the DC-to-AC voltage inverter.

DC-to-AC Voltage Inverter

The DC-to-AC voltage inverter converts DC bus voltages to AC voltages. Two power transistors are used in a half H-bridge configuration with bipolar DC voltage rails. The output of the high side driver from gate drive circuitry is the gate voltage for the upper transistor in the half H-bridge while the output of the low side driver in gate drive circuitry is the input for the lower transistor in the half H-bridge. The output of the DC-to-AC voltage inverter drives a resistive load.

Hardware Testing

High and Low Side Drivers

High and low side drivers in gate drive circuitry were tested independently of one another to determine whether or not the output switches the power transistors in the DC-to-AC voltage inverter as desired. The sync output of a function generator was used as the input to the HCPL-3120.

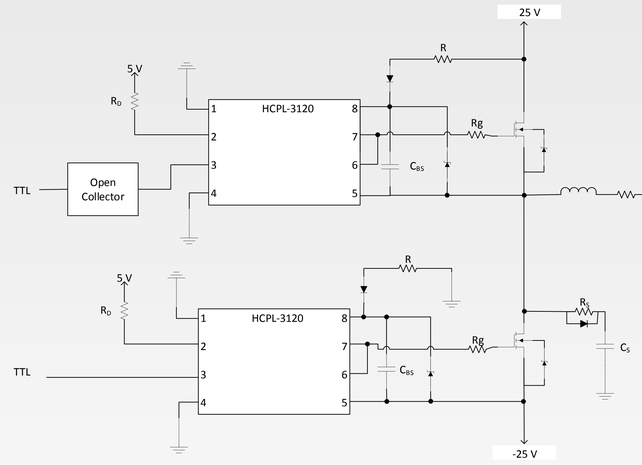

Fig. 3. Test circuit used to test functionality of the high and low side drivers.

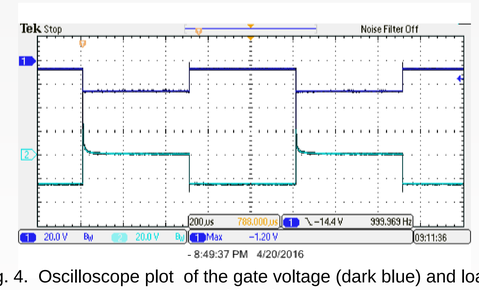

Fig. 4. Oscilloscope plot of the gate voltage (dark blue) and load voltage (light blue) for the low side driver.

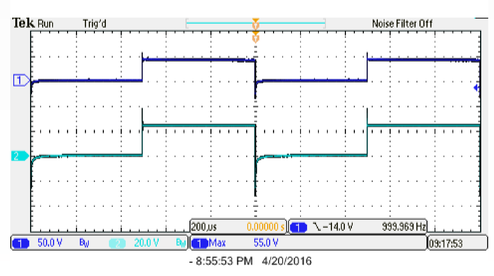

Fig. 5. Oscilloscope plot of the gate voltage (dark blue) and load voltage (light blue) for the high side driver.