Three-phase Pulse Width Modulated AC/DC Rectifier and DC/AC Inverter

ECE-499 Presentation

Carmen Ngo

Introduction

Electrical vehicles (electric cars/EVs) have become more popular as people are becoming increasingly aware of the long-term effects of the use of fossil fuels.

Electric cars have batteries that run on direct current (DC) power. The motor can run on either alternating current (AC) or DC power. DC powered motors need a DC to DC converter to step up and step down voltage. AC powered motors also need an inverter to convert the DC power to AC power.

Goals

Goals

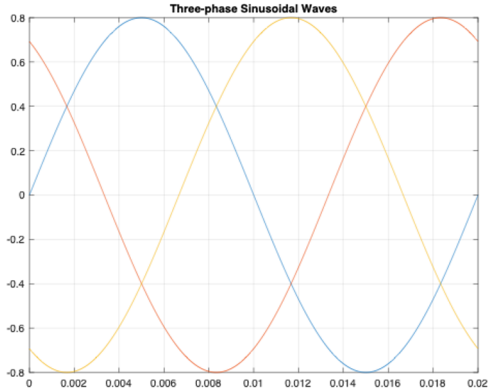
- Successfully replicate and understand the power flow in an electric vehicle
- Mimic driving and braking in an electric vehicle
  - Driving using an inverter circuit
    - Invert DC power to three-phase AC power
  - Braking using a rectifier circuit
    - Convert three-phase AC power to DC power

*Three-phase electric power is a common method of AC electric power generation, transmission, and distribution.

Performance Criteria

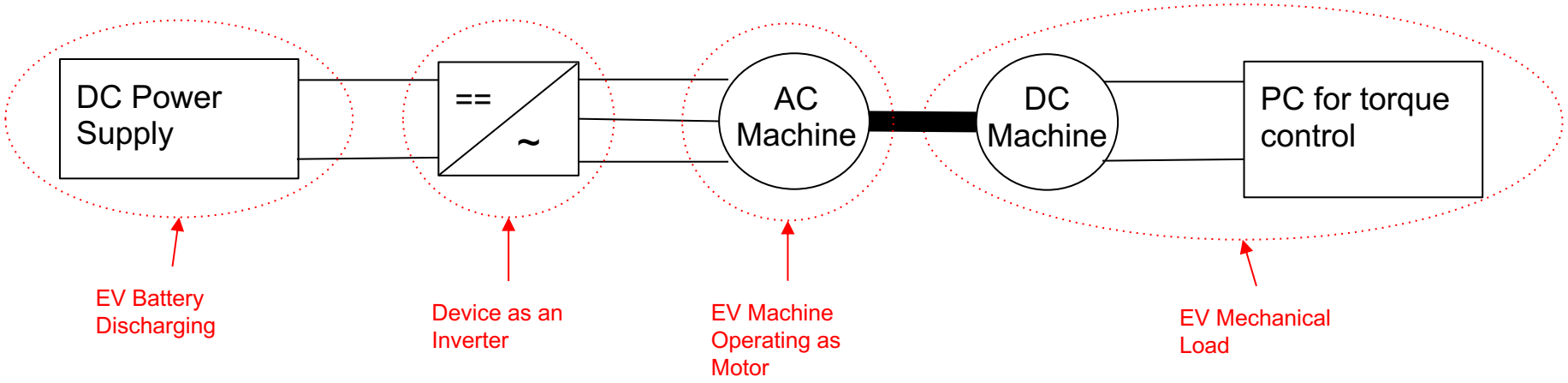
Performance criteria

- Driving and braking systems should run continuously and start as soon as power is provided
- Three-phase AC signals should be 50 Hz and 120 degrees phase shifted
  - Each period is 20 ms
- Driving system should move the three-phase AC motor
- Braking system should power a power resistor



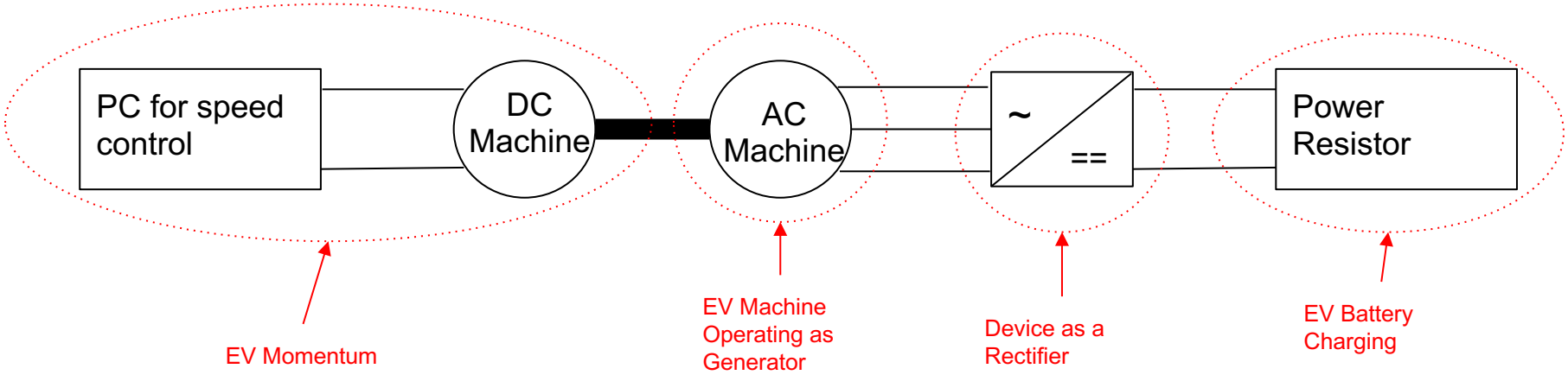
Design and implementation

Driving in an EV



Design and implementation (cont.)

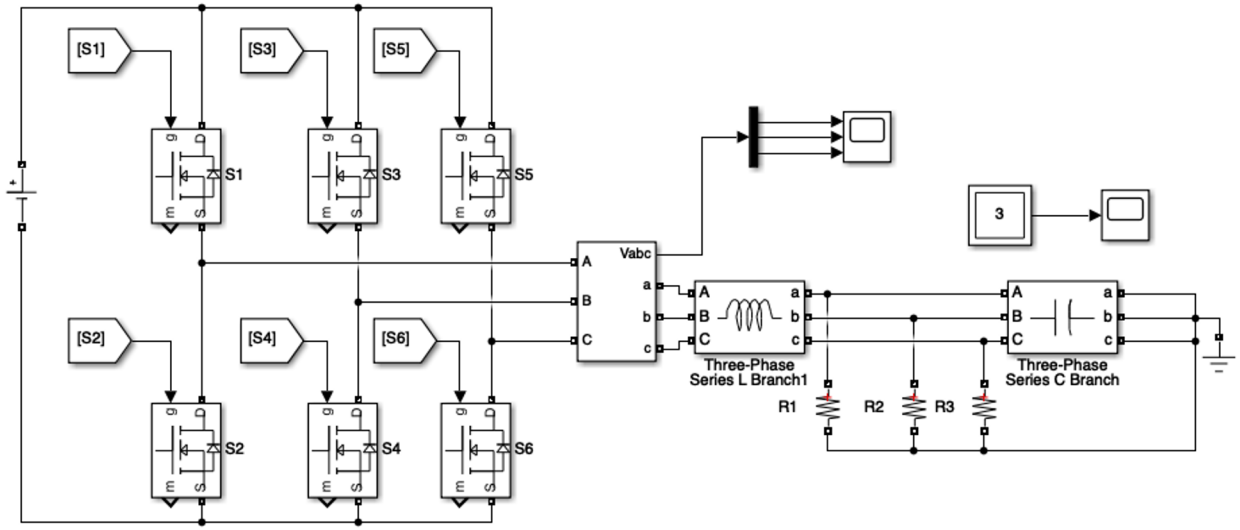
Braking in an EV



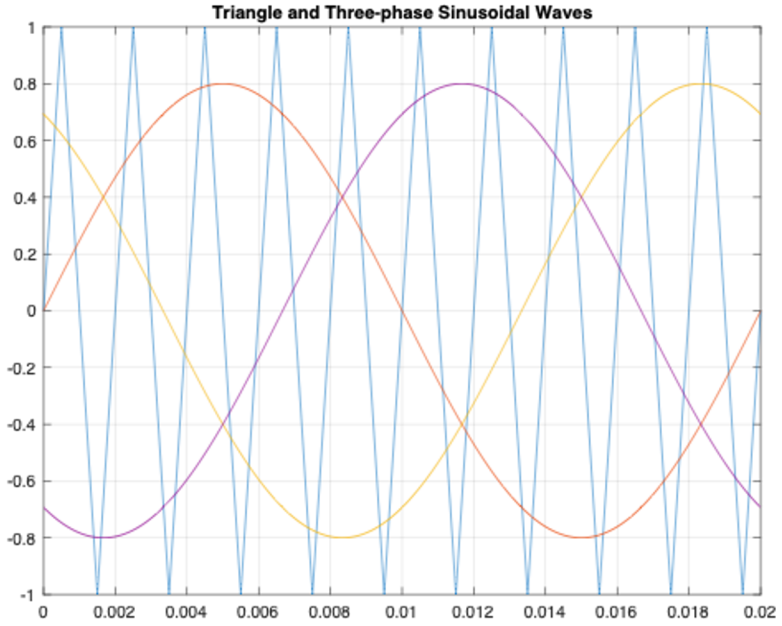
Design and implementation (cont.)

Inverter Circuit

- IRS2184 Half-bridge Gate Drivers
- IRFP054 N-channel MOSFETs
- Sinusoidal Pulse Width Modulation (SPWM)
- LC filter for fc = 138.5 Hz



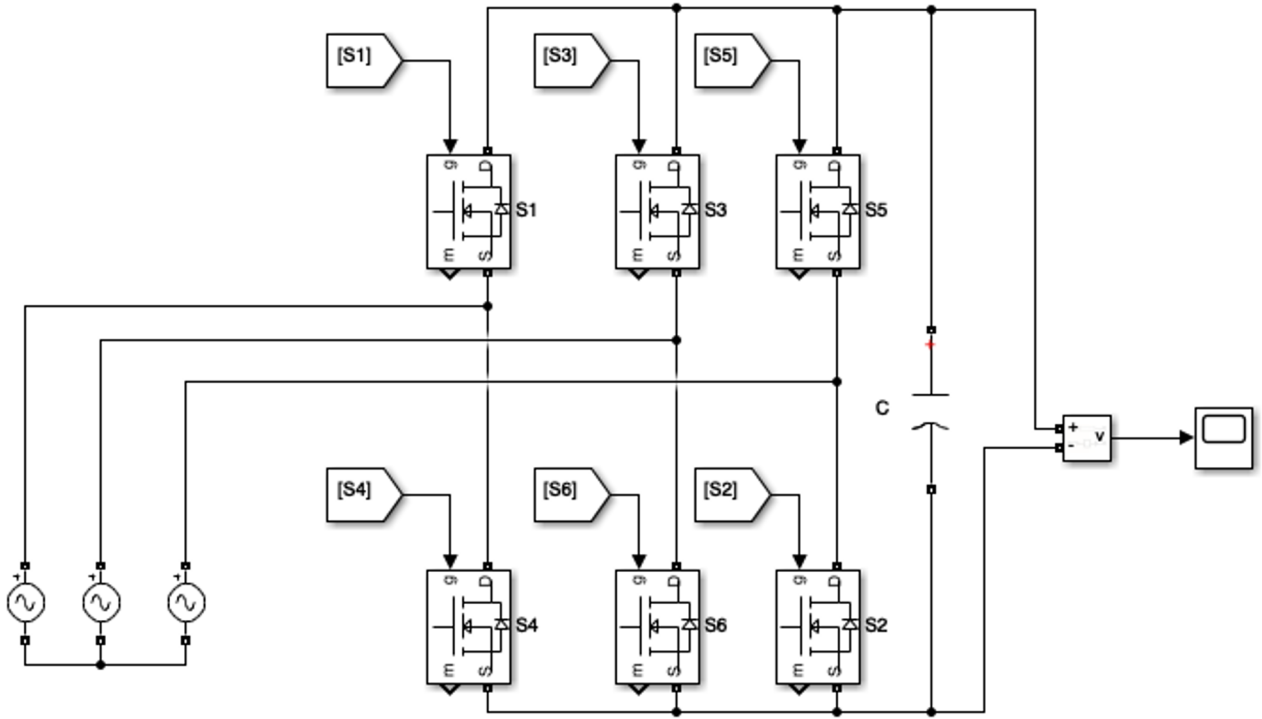
Sinusoidal Pulse Width Modulation (SPWM)



Design and implementation (cont.)

Rectifier Circuit

- MIC4422 Low-side Gate Drivers
- IRFP054 N-channel MOSFETs
- Capacitor filter



Design and implementation (cont.)

Top

MOSFET1

MOSFET3

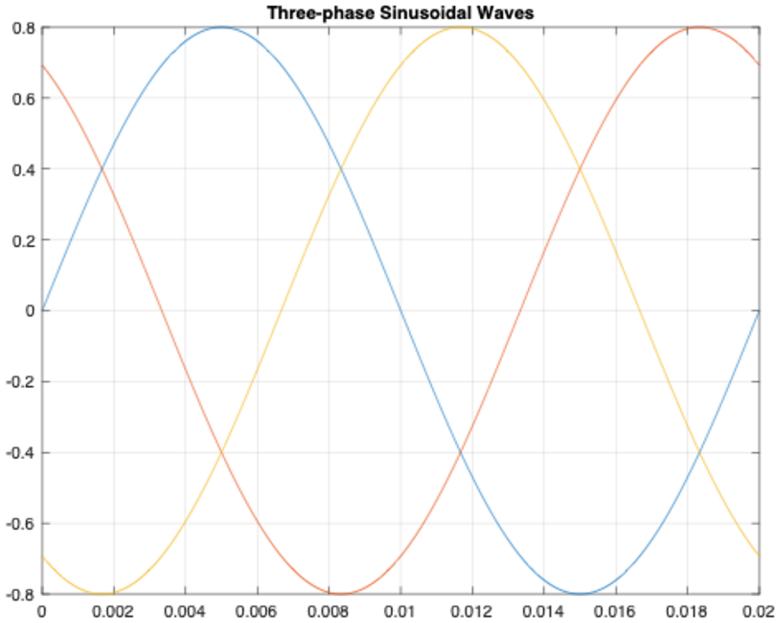
MOSFET5

Bottom

MOSFET2

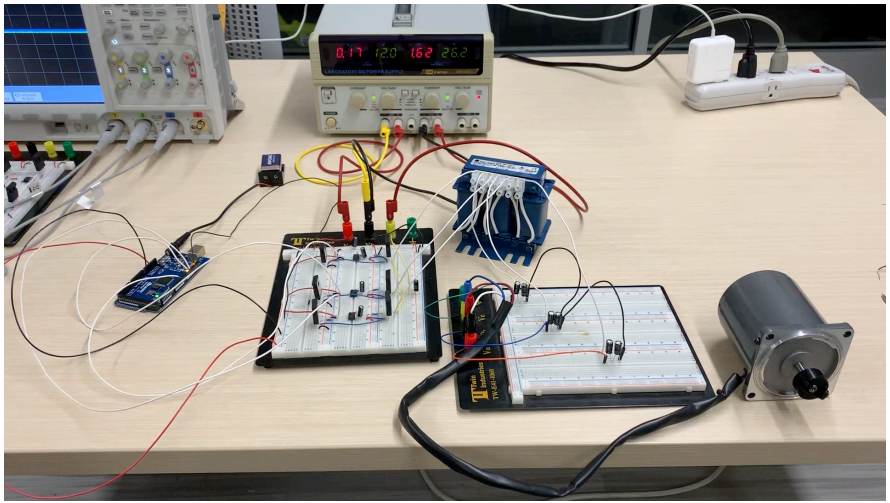
MOSFET4

MOSFET6



Results with comparison to performance criteria

- **Driving system runs continuously and starts as soon as power is provided**
- **Driving system moved the three-phase AC motor**
  - Starts physically running when power is ~24V
  - Can start at ~20V with help
  - Draws ~0.62A at ~24V

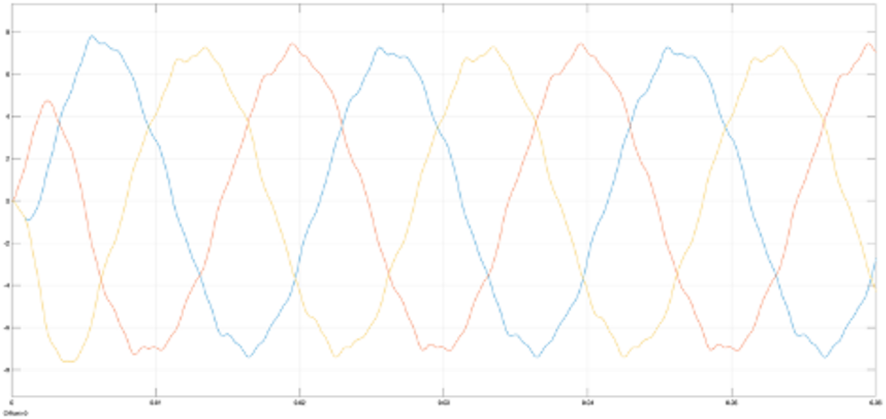


Results with comparison to performance criteria

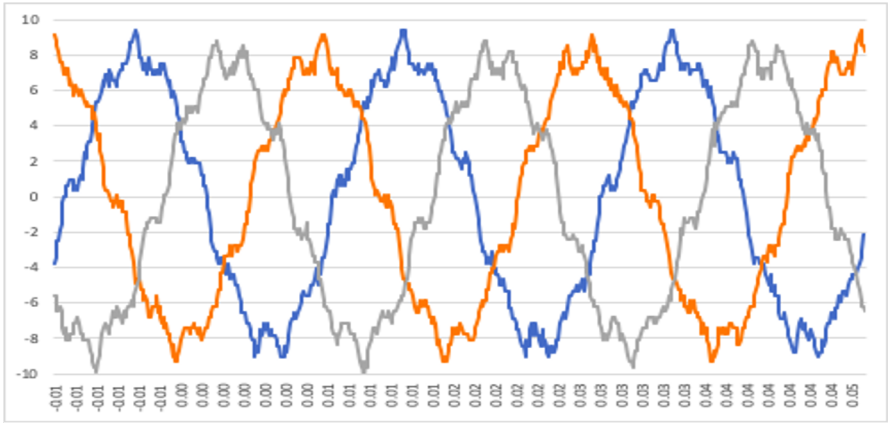
Driving system

- **Output frequency of each of the three-phase AC signals is 50 Hz and 120 degrees phase shifted**

SIMULINK



Actual

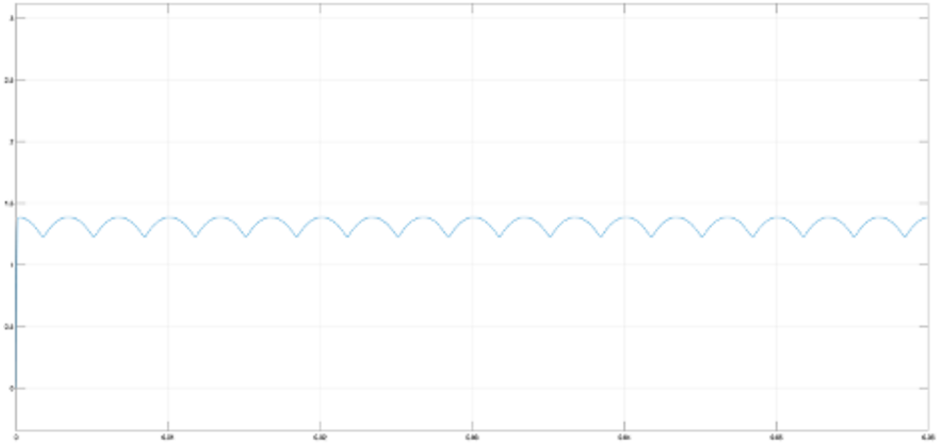


Results with comparison to performance criteria

Braking system

- Braking systems should run continuously and start as soon as power is provided
- Braking system should power a power resistor

SIMULINK



- Rectifier circuit is built
- Arduino code is written

Conclusions

Electric vehicles require inverters and converters to work. The inputs into both the inverter and rectifier circuits were hard-coded in Arduino, which was necessary for the inverter circuit, but the rectifier circuit could have used real-time input signals. The rectifier can still be worked on, but the driving system works as expected.

Further Work

- Bidirectional power flow
- Real-time AC input signals for rectifier
  - Non-inverting amplifier
  - AC permanent magnet motor
- Include mechanical load in driving scenario
- Feedback control for real-time tuning of magnitude and frequency of inverter output, and average value for rectifier output
- Feedback for speed, torque, or position control of a motor load