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ENGINE Engineering curricula modernization in renewable energy in Albanian Universities

VIRTUAL LABS USER MANUAL

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Virtual Laboratories

Instructions for use of simulation models

Simulation models have been prepared in the GeckoCIRCUITS.

To start creating circuits with Gecko Circuits you need to download the Gecko executable:
https://drive.google.com/file/d/1KvrqS8F8ZZqVC6giJXMYxLxwi9ANaUP4/view?usp=sharing

and the jdk (for Windows):
https://download.java.net/java/GA/jdk17.0.2/dfd4a8d0985749f896bed50d7138ee7f/8/GPL/openjdk-17.0.2_windows-x64_bin.zip

Already prepared and uploaded on the platform models only require the Java Runtime Environment (JRE) (available at: http://java.com/download/) to run.

Downloading simulation model

To download the simulation model click the corresponding link in the Virtual Labs area located inside Moodle course https://moodle.engineproject.eu/course/view.php?id=29.

Design of simulation models

All models include:

1. The diagram of the electrical part,
2. Measuring and estimation blocks,
3. Control System (if necessary) and
4. Scopes – for presenting the results of the simulation.

Performing the simulation

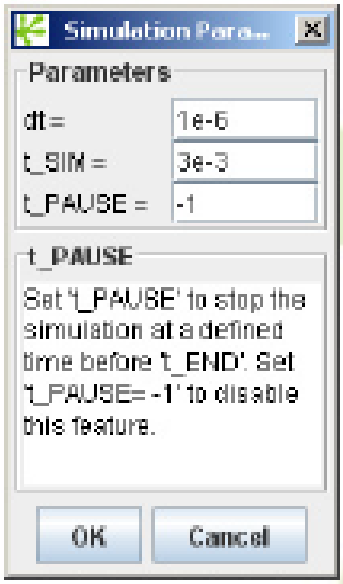
After opening the downloaded file, select Simulation> Init & Start from the menu. This will start the calculations, which percentage progress will be displayed at the top of the window. After the end of the simulation process a message will appear (Stopped after ... [s]).

The simulation results are shown after opening the corresponding scope by double clicking on its symbol.

Changing conditions of the simulation

To change a component's parameters, double click on its symbol to open its parameters dialogue.

Open the dialog Simulation Parameters via menu Simulation >>_Parameter to define the simulation timestep (dt) and duration (t_SIM).



Full-Wave Bridge Rectifier (FWBR)

Objective

Plotting input and output waveforms of a full-wave bridge rectifier.

Circuit operation

As shown in Fig. 1, the FWBR circuit is composed of four diodes connected in a bridge with no need for a center-tap transformer. Diodes D_1 and D_2 conduct the current during the positive half- cycles of the voltage, whereas diode D_3 and D_4 become conducting during the negative half cycles.

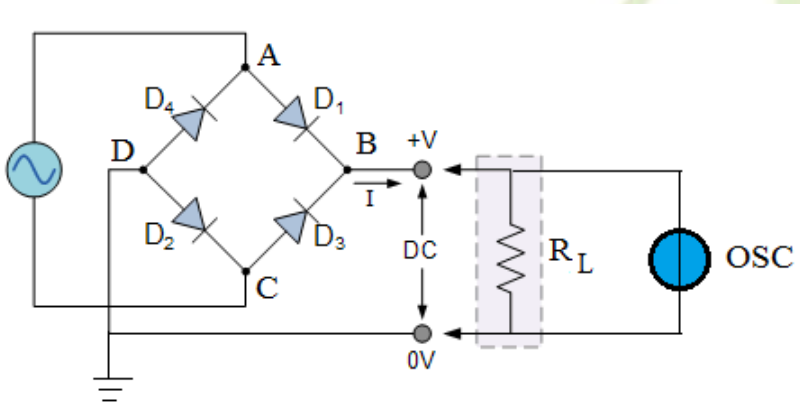


Fig. 1. Full-wave bridge rectifier circuit.

During the positive half-cycle of the input voltage (0 - π), diodes D_1 and D_2 are forward biased and diodes D_3 and D_4 are reverse biased. Therefore, on point B, the positive-half cycle presents, and the current will pass through resistor R_L and diode D_2 to point C. When the input wave changes to the negative half (π - 2π), diodes D_3 and D_4 are forward biased and diodes D_1 and D_2 become then reverse biased. This part of the input wave will present as a positive cycle on the load. The current path starts from point A through diode D_4, resistor R_L and diode D_3 to point C.

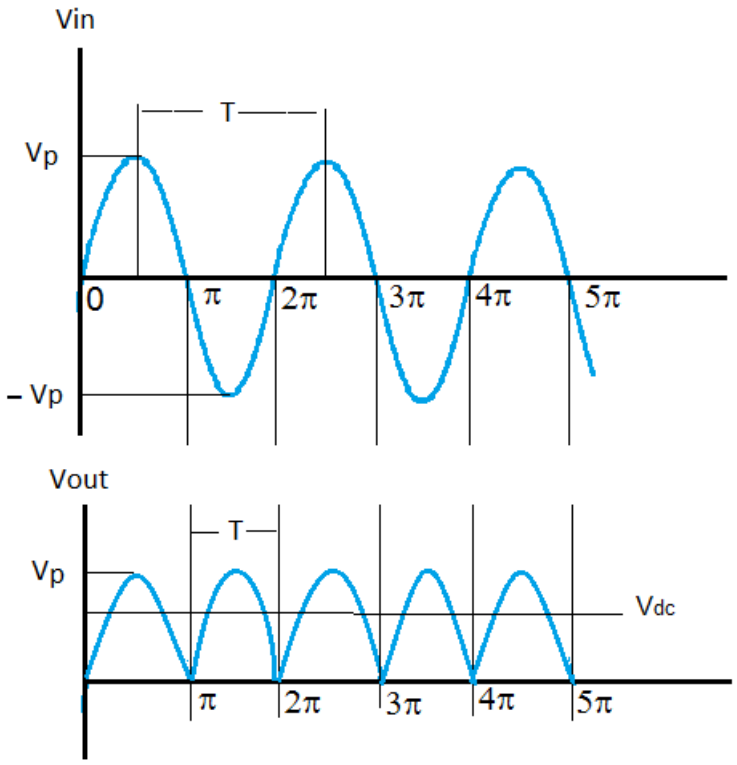
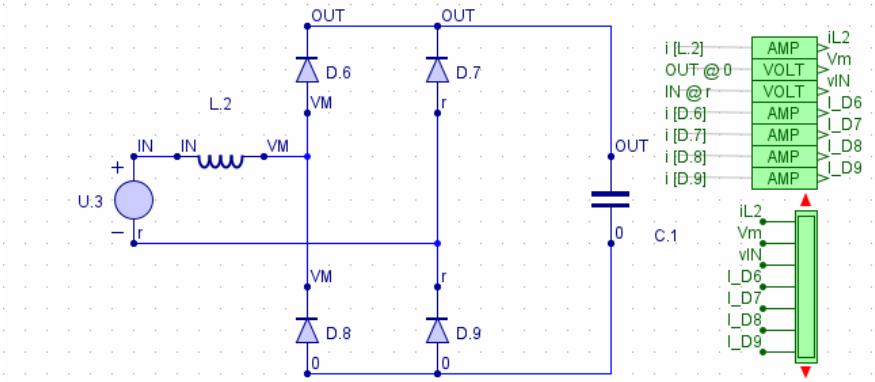


Fig. 2. Full-wave bridge rectifier waveforms

Procedure

[1] Open FWBR.jar
[2] Plot the AC input voltage of the rectifier and measure its frequency.
[3] Plot the DC output voltage of the rectifier.
[4] Change the capacitor to 10uF, 50uF, 100uF and repeat step 3. What do you observe?


OUT
OUT
D.6
D.7
L.2
VM
r
IN
IN
VM
OUT
U.3
r
0
C.1
VM
r
D.8
D.9
0
0
i [L:2]
OUT @ 0
IN @ r
i [D:6]
i [D:7]
i [D:8]
i [D:9]
AMP
VOLT
VOLT
AMP
AMP
AMP
AMP
iL2
Vm
vIN
I_D6
I_D7
I_D8
I_D9
iL2
Vm
vIN
I_D6
I_D7
I_D8
I_D9

DC-DC Converters

Circuit Diagrams

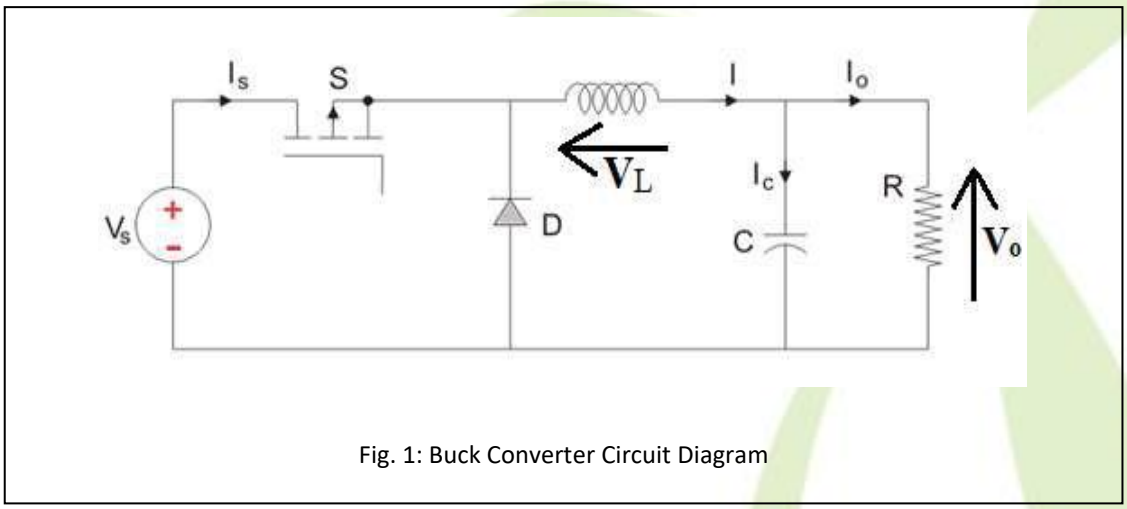


Fig. 1: Buck Converter Circuit Diagram

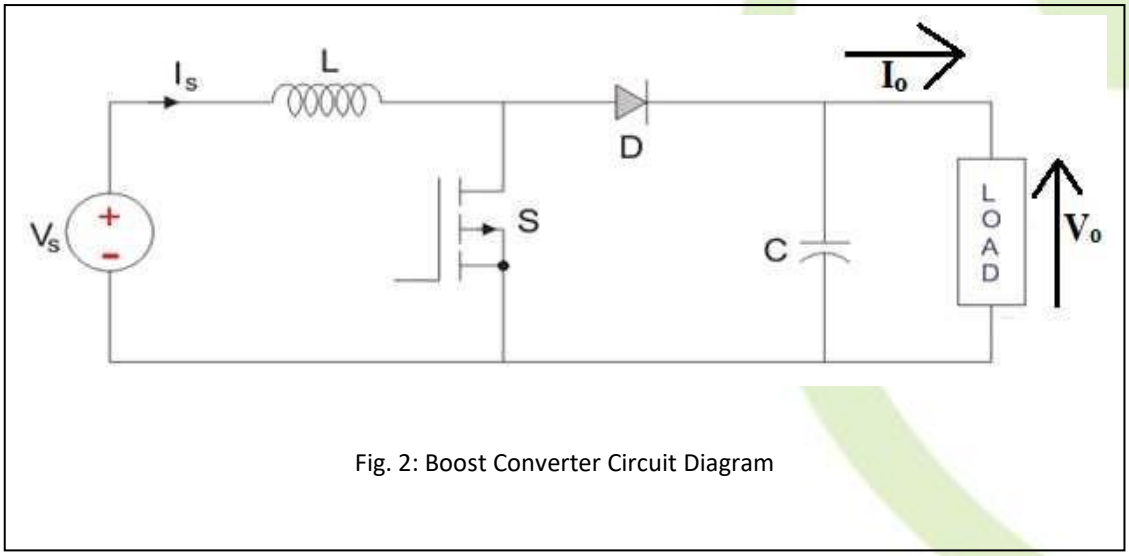


Fig. 2: Boost Converter Circuit Diagram

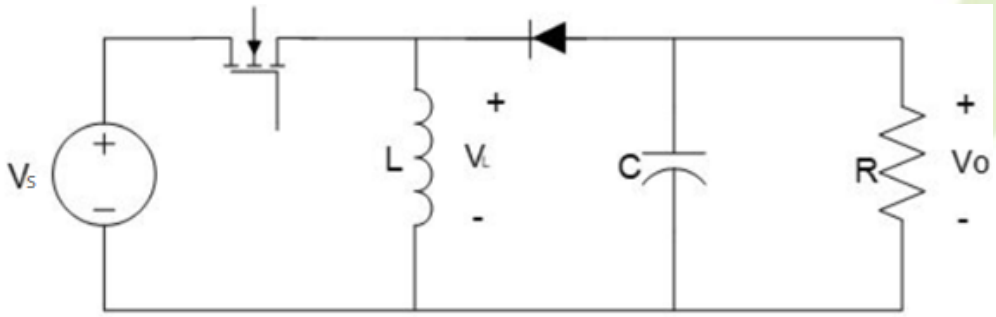


Fig. 3: Buck-Boost Converter Circuit Diagram

Theory

DC-DC converters are also known as Choppers. A chopper is basically a dc to dc converter whose main function/usage is to create adjustable dc voltage from fixed dc voltage sources through the use of semiconductors. The controlled switch in these converters is turned on and off by using Pulse Width Modulation (PWM). PWM can be time based or frequency based. Frequency based modulation has disadvantages like a wide range of frequencies to achieve the desired control of the switch which in turn will give the desired output voltage. This leads to a complicated design for the low-pass LC filter which would be required to handle a large range of frequencies. Time based Modulation is mostly used for DC-DC converters. It is simple to construct and use. The frequency remains constant in this type of PWM modulation. Duty Cycle, $D = \frac{T_{ON}}{T_{ON}+T_{OFF}}$

Buck Converter: A buck converter as shown in Fig. 1 (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor). The input voltage source is connected to a controllable solid state device which operates as a switch. The solid state device can be a Power MOSFET or IGBT. Thyristors are not used generally for DC-DC converters because to turn off a Thyristor in a DC-DC circuit requires another commutation which involves using another Thyristor, whereas a Power MOSFET can be turned off by simply having the voltage between its GATE and SOURCE terminals. The second switch used is a diode. The switch and the diode are connected to a low-pass LC filter which is appropriately designed to reduce the current and voltage ripples. The load is a purely resistive load. Output voltage is given by $V_o = D \cdot V_S$, where D is duty cycle and V_S is the input voltage.

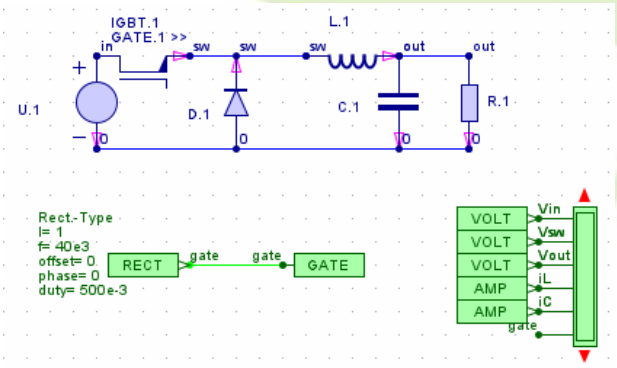
Boost Converter: A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is also a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element. The input voltage source is connected to an inductor. The solid-state device which operates as a switch is connected across the source. The second switch used is a diode. The diode is connected to a capacitor, and the load and the two are connected in parallel as shown in Fig. 2. The inductor connected to input source leads to a constant input current, and thus the Boost converter is seen as the constant current input source. And the load can be seen as a constant voltage source. Output voltage is given by $V_o = \frac{1}{1-D} \cdot V_S$, where D is duty cycle and V_S is the input voltage.

Buck Boost converter: Another basic dc-dc converter is buck-boost converter shown in Figure 3. The output voltage of a buck-boost converter can be either higher or lower than the input voltage. If D>0.5, the output voltage is greater than the input voltage. if D < 0.5, the output voltage is less than the input voltage. Output voltage is given by $V_o = -\frac{D}{1-D} \cdot V_S$, where D is duty cycle and V_S is the input voltage.

Circuit Operation

Buck Converter

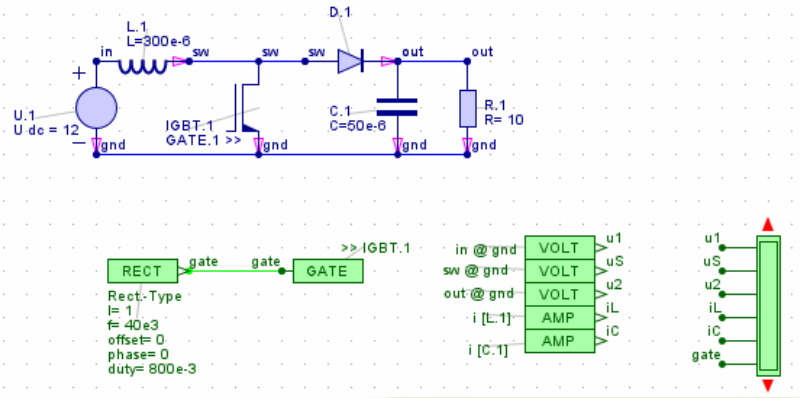
Use buck_cnv.jar to simulate buck converter operation. Set DC Input to 48 V and vary the duty cycle from 40% to 80% with 10% steps



Duty Cycle	Theoretical output voltage	Simulated output voltage
40%		
50%		
60%		
70%		
80%		

Boost Converter

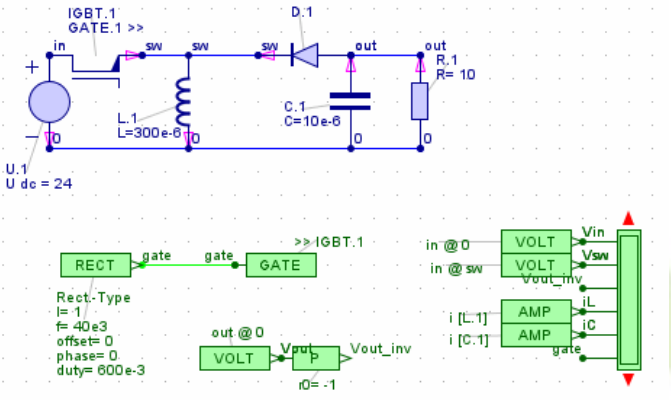
Use boost_cnv.jar to simulate boost converter operation. Set DC Input to 12 V and vary the duty cycle from 40% to 80% with 10% steps



Duty Cycle	Theoretical output voltage	Simulated output voltage
40%		
50%		
60%		
70%		
80%		

Buck-Boost Converter

Use buckboost_cnv.jar to simulate buckboost converter operation. Set DC Input to 24 V and vary the duty cycle from 10% to 90% with 10% steps.



Duty Cycle	Theoretical output voltage	Simulated output voltage
10%		
20%		
30%		
40%		
50%		
60%		
70%		
80%		
90%		

INVERTERS

Introduction

Inverters are also called dc-to-ac converters. An inverter converts a fixed dc voltage to a symmetrical ac voltage of desired frequency and amplitude. Inverters are widely used in industrial applications such as uninterruptible power supplies (UPS), induction motor and variable-speed ac servo motor drives.

Principles of Inverters

Inverters convert dc power to ac power at some desired output voltage and frequency, Inverters can be classified into two types: 1) single-phase inverters, and 2) three-phase inverters. The basic circuits of single-phase and three inverters are shown in Figures 1 and 2 respectively. The dc input voltage is fixed and may be a battery, solar cell, fuel cell, or other dc source. The switching device can use each type of controlled turn-on and turn-off devices such as thyristors. BJTs, MOSFETs, and IGBTs

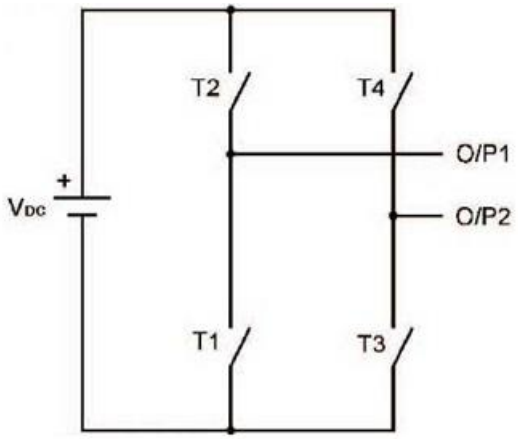


Figure 1:single phase inverter

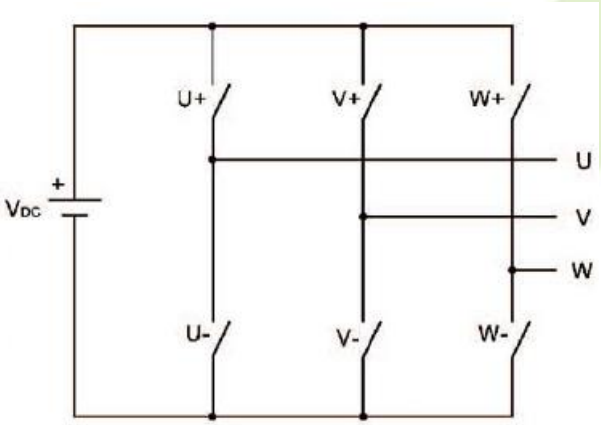


Figure 2: three phase inverter

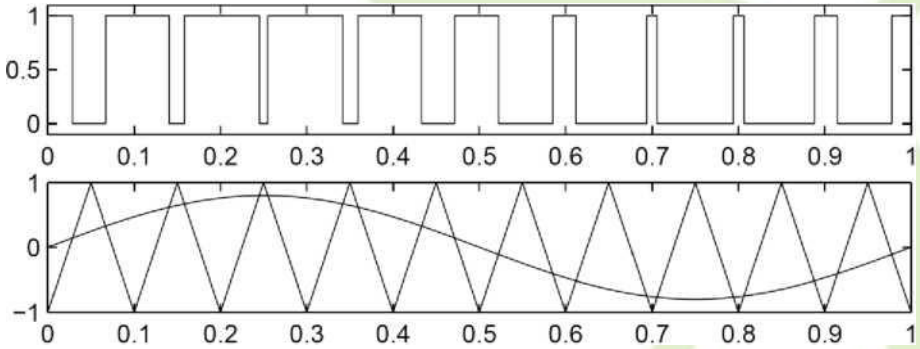
The switching devices of the same arm (e g., T1 and T2, U+ and U-) cannot conduct at the same time. Since the turn-off time of power switching devices is greater than turn-on time, therefore a delay called the dead time must be introduced to avoid a short circuit. The dead time depending on the turn-off time of power devices is usually specified as 2-3 times the tum-on time.

To control the on- and off-time of each switching device, a gating signal should be applied at an appropriate time. The gating signal may be square or PWM voltage. Generally the inverters are controlled by using Sinusoidal Pulse-Wldth Modulation (SPWM) technique. A SPWM wave is produced by comparing a sinusoidal reference signal to a higher frequency triangular carrier wave. The frequency of reference signal determines the output frequency of inverter, the peak value of reference signal controls the average output voltage, and the number of pulses per half-cycle, P, is determined by the carrier frequency. SPWM can eliminate the harmonics which are less than or equal to 2P-1-order.

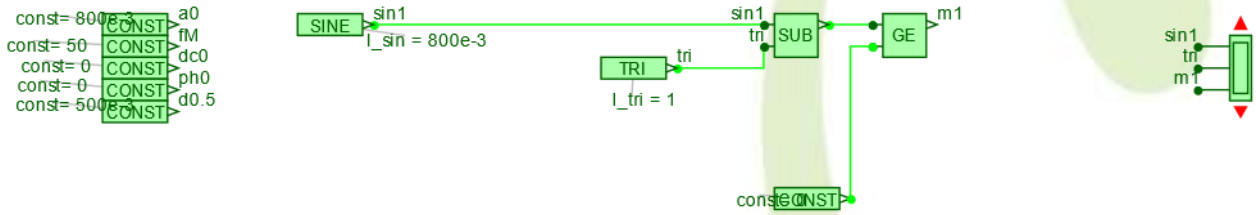
Single-phase pwm controller

In SPWM control, the widths of pulses are varied by changing the amplitude of the reference signal and the number of pulses is determined by the carrier frequency.

The modulator uses a voltage value to calculate a corresponding pulse width signal (PWM). Its operation is described using the below figure: the switching state is S = 1 when the sinusoidal control signal is bigger than the triangular signal, otherwise S = 0.



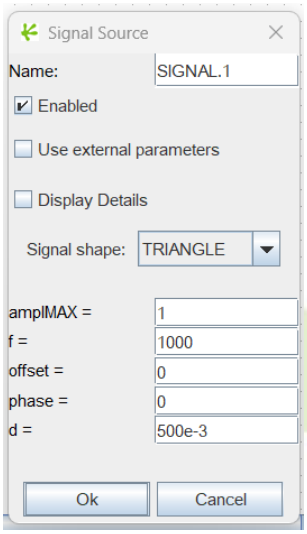
Use spwm.jar to familiarize yourself with SPWM operation.

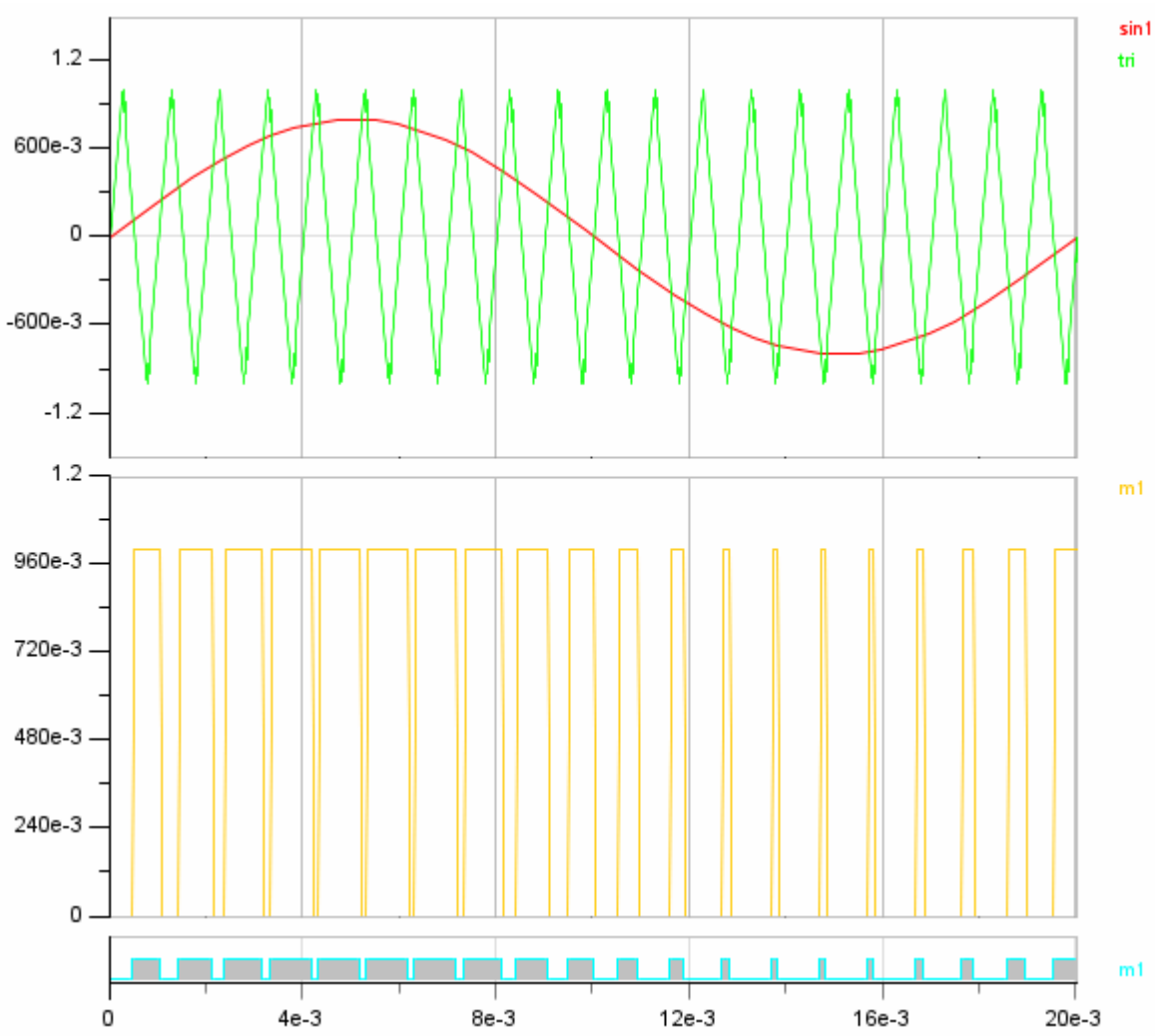


Double click on the TRI icon

to change the carrier frequency. Then run the simulation using init&start selection from the dropdown menu simulation and open the scope to

view the output of the modulator.


Signal Source
Name:
SIGNAL.1
Enabled
Use external parameters
Display Details
Signal shape:
TRIANGLE
amplMAX =
1
f =
1000
offset =
0
phase =
0
d =
500e-3
Ok
Cancel

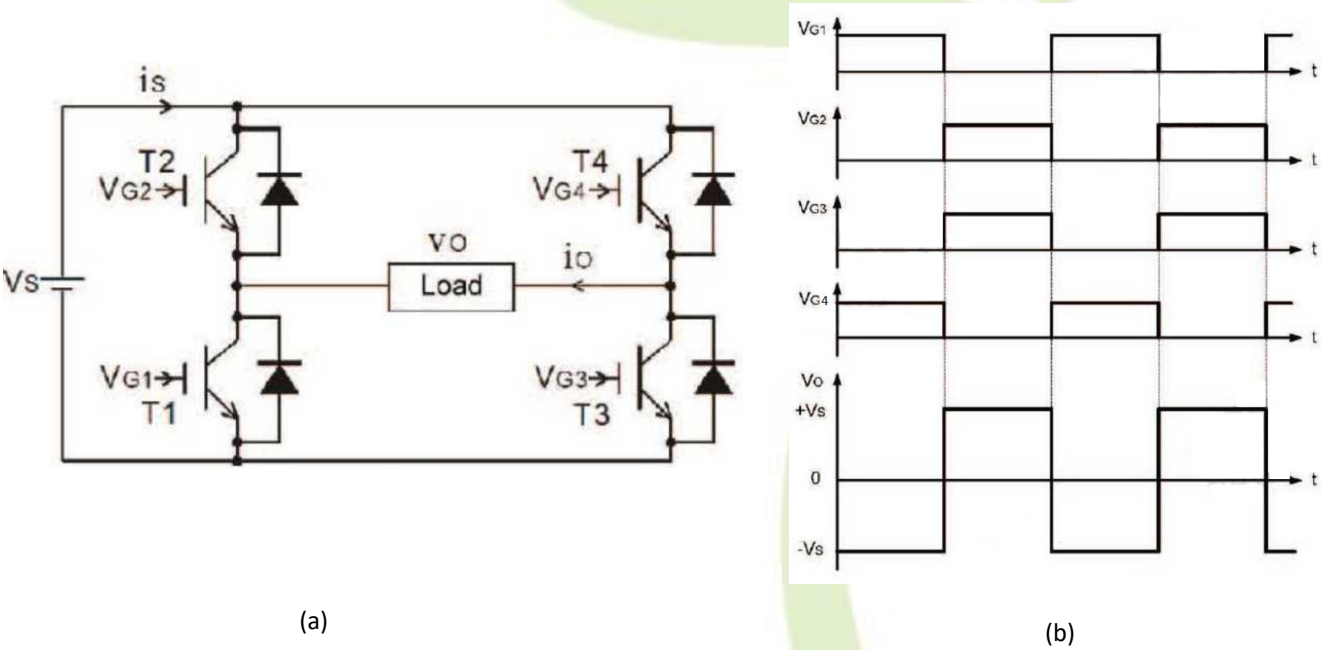

sin1
tri
1.2
600e-3
0
-600e-3
-1.2
m1
960e-3
720e-3
480e-3
240e-3
0
m1
0
4e-3
8e-3
12e-3
16e-3
20e-3

Simulation of single-phase sine pwm inverter

Theory

The power circuit of single-phase full-bridge inverter is shown in Figure 1(a). When IGBTs T2 and T3 are turned on at the same time, the supply voltage Vs appears across the load. When IGBTs T1 and T4 are turned on simultaneously, the output voltage across the load is reversed and is -Vs.

The square gating signals and the output voltage of the single-phase inverter are shown in Figure 1(b). If the gating signals are PWM signals, the output voltage is therefore a PWM wave. With an inductive load, the output current is a sinusoidal waveform.



(a) (b)

Figure 1: Single phase full bridge inverter (a) and its output (b)

Use 1phinv.jar to simulate the operation of a full bridge single phase inverter.

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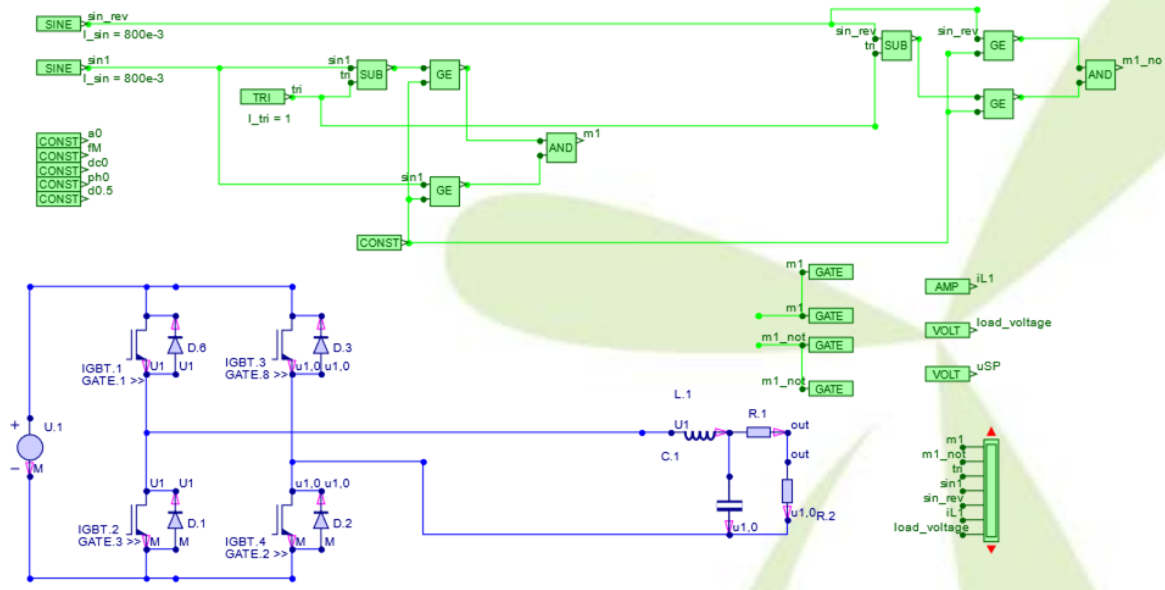

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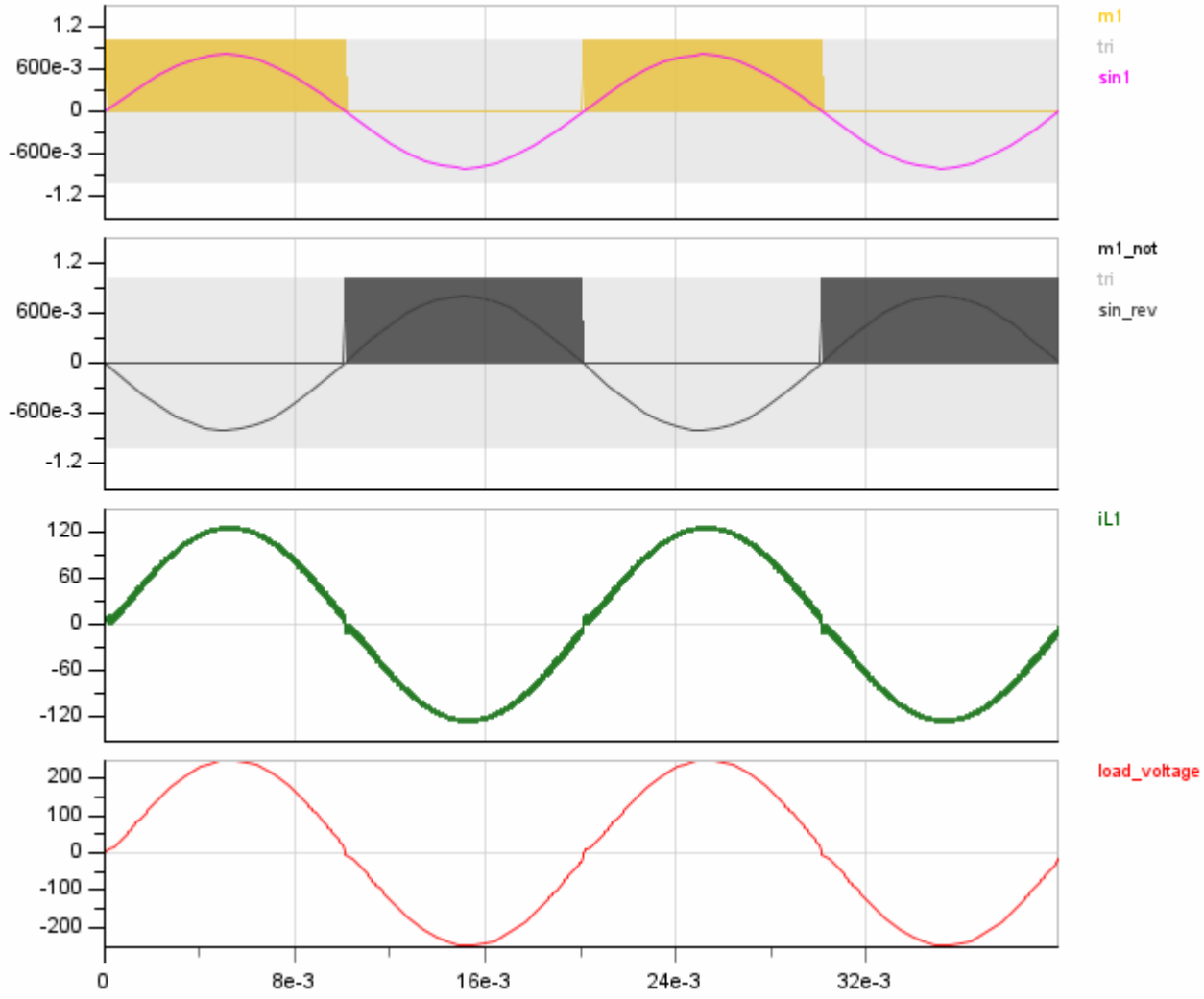
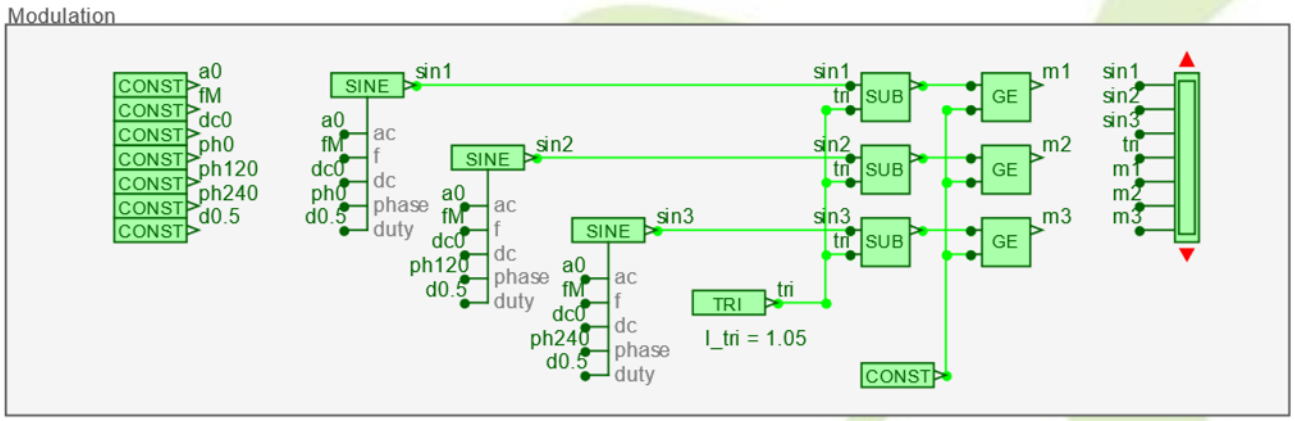
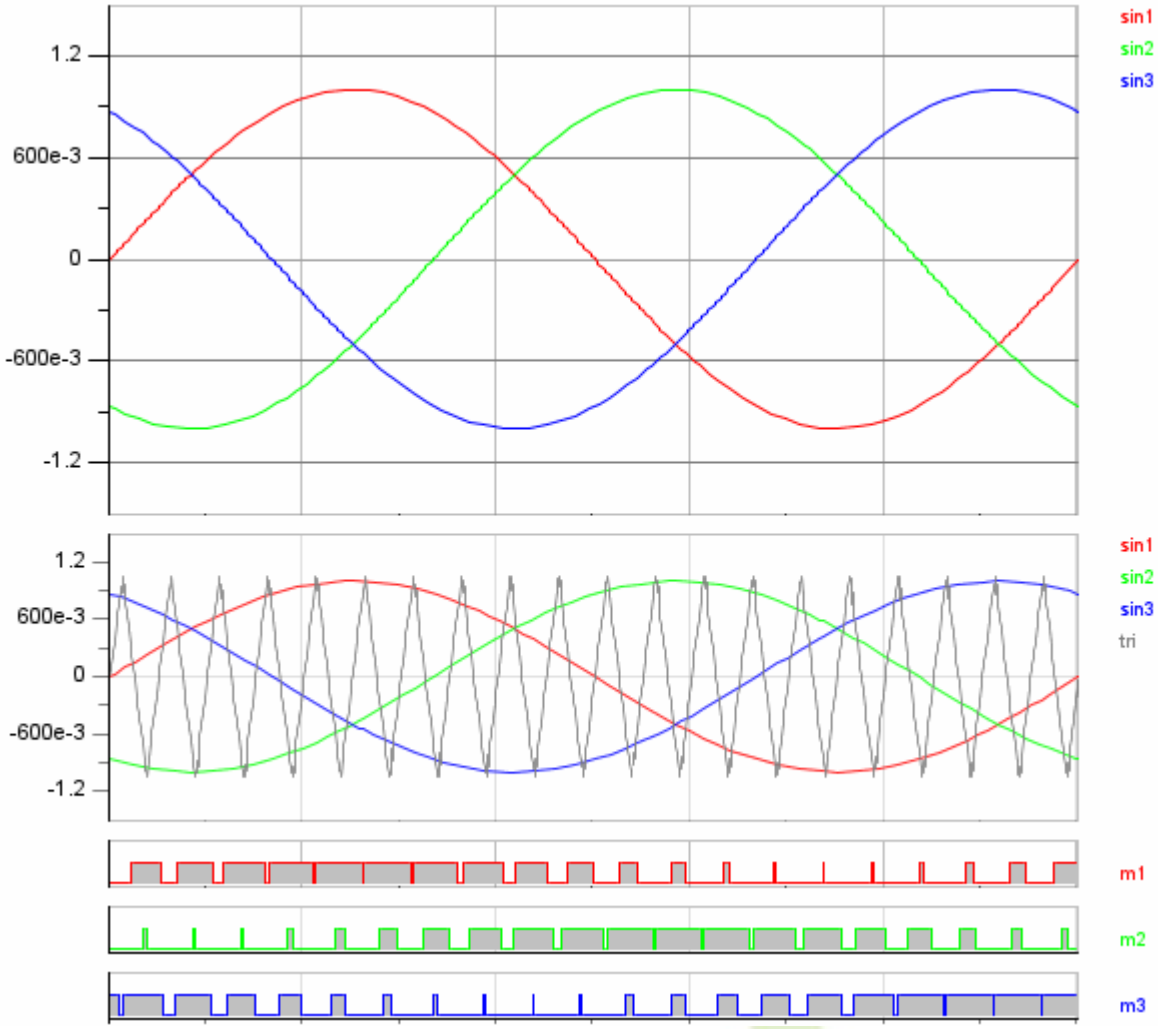

1.2
600e-3
0
-600e-3
-1.2
m1
tri
sin1
1.2
600e-3
0
-600e-3
-1.2
m1_not
tri
sin_rev
120
60
0
-60
-120
iL1
200
100
0
-100
-200
load_voltage
0
8e-3
16e-3
24e-3
32e-3

Three-phase pwm controller

Use 3pwm.jar to simulate the operation of a three-phase sine PWM controller.




1.2
600e-3
0
-600e-3
-1.2
sin1
sin2
sin3
1.2
600e-3
0
-600e-3
-1.2
sin1
sin2
sin3
tri
m1
m2
m3

Simulation of three phase sine pwm inverter

Theory

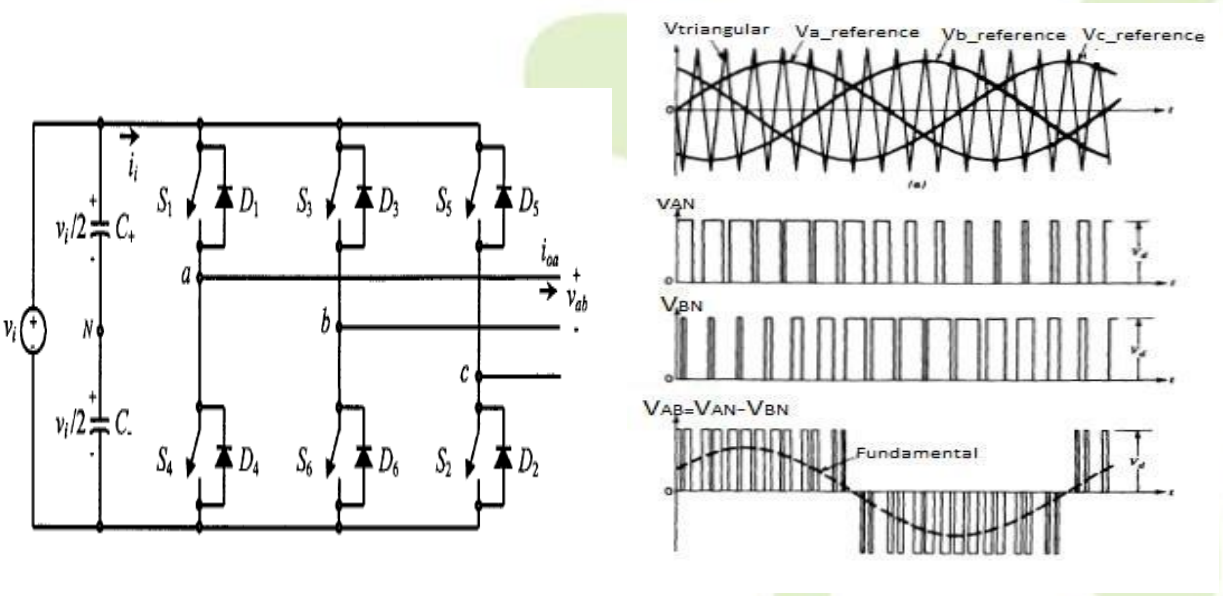


Figure shows the three-phase inverter circuit with on and off controlled switches such as MOSFET or IGBT. Sine PWM pulses are used to gate the switches. Upper switches are gated with signals obtained by comparing three reference sine waves phase shifted by 120^0 with a high frequency triangular carrier wave. Switches are ON when amplitude of corresponding reference sine wave is greater than amplitude of triangular carrier wave. Lower switches are gated with a gate signal which is complement of upper switches of same leg.

Use 3phinv.jar to simulate the operation of a three-phase inverter.

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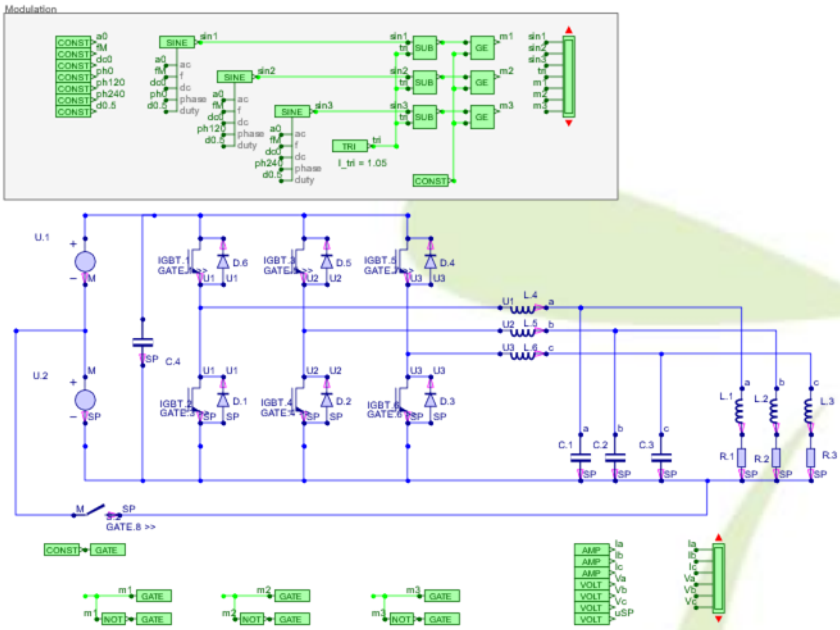

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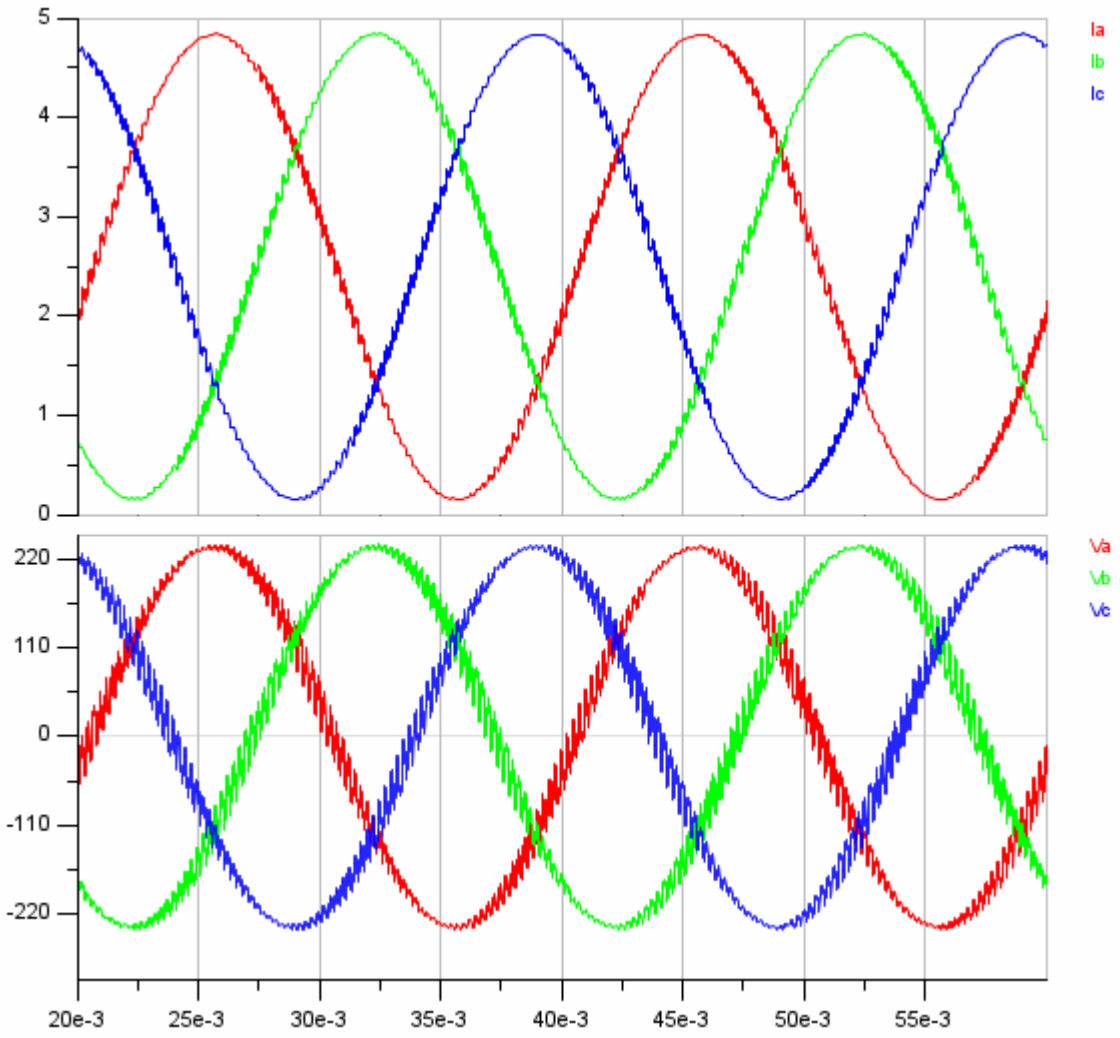
5
4
3
2
1
0
Ia
Ib
Ic
220
110
0
-110
-220
Va
Vb
Vc
20e-3
25e-3
30e-3
35e-3
40e-3
45e-3
50e-3
55e-3