

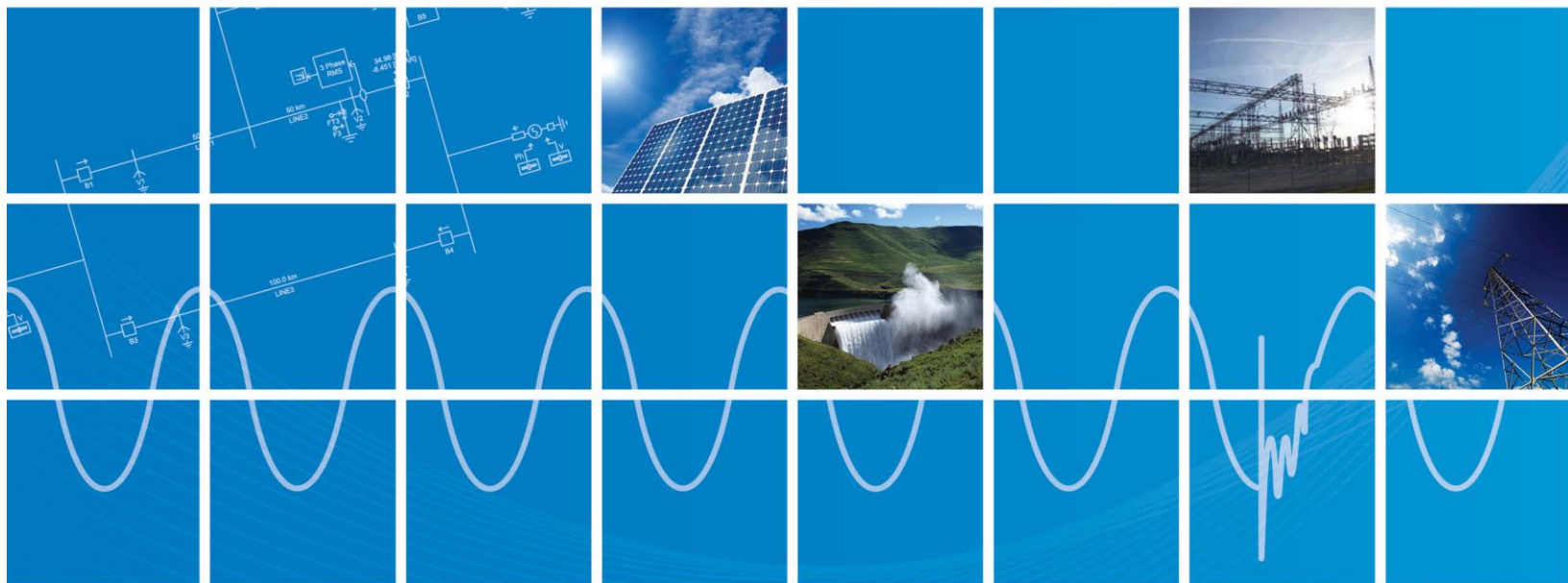


# Power Electronic Switch Component

For PSCAD Version 5.0

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Initial



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## 1. OVERVIEW

### 1.1. Diode

The diode ON and OFF states are controlled by the voltage and current conditions across the device itself. The diode assumes a fixed small ON and a large OFF resistance. Conduction commences when the device is forward biased and the forward voltage exceeds the Forward Voltage Drop input parameter. The diode turns OFF at current zero and remains OFF as long as it is reverse biased.

The V-I characteristic for the diode model is shown in [Figure 1](#).

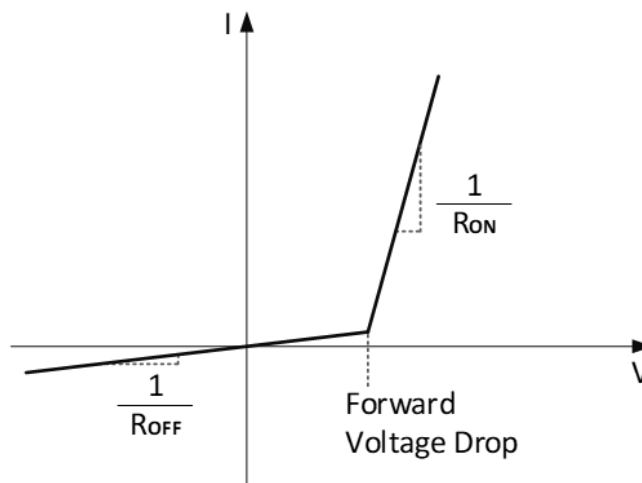


Figure 1: Diode V-I characteristic Curve

Both ON and OFF events use the Interpolation Algorithm to calculate the instant of switching. Thus, turn ON occurs exactly when forward voltage reaches the Forward Voltage Drop and turn OFF occurs exactly when current reaches zero.

**NOTE:** Reverse recovery time (i.e. the time for which a finite reverse current flows in the device, following a turn OFF) of the diode is assumed zero. If the ON resistance is zero or smaller than the switching threshold value, the closed state will be modeled as an ideal short circuit.

## 1.2. Thyristor

The thyristor is usually latched ON by a firing pulse supplied to the gate terminal, but is turned OFF according to voltage and current conditions across the device itself. An external control signal is required to generate the gate firing pulses.

The thyristor assumes a fixed small ON and a large OFF resistance. The thyristor state will change under the following conditions:

1. The forward bias voltage across the device is greater than or equal to the Forward Voltage Drop parameter input AND the gate signal goes from 0 to 1 (i.e. firing pulse is issued).
2. The forward bias voltage across the device is greater than or equal to the Forward Voltage Drop parameter input AND the gate signal is pre-set to 1 (i.e. firing angle = 0°). A turn ON under this situation is NOT interpolated (for an interpolated turn ON with firing angle = 0°, use the Diode).
3. The forward bias voltage across the device is greater than or equal to Forward Break-Over Voltage parameter input.
4. Turning OFF occurs with the device current reaching zero.

The V-I characteristic for the thyristor model is shown in [Figure 2](#).

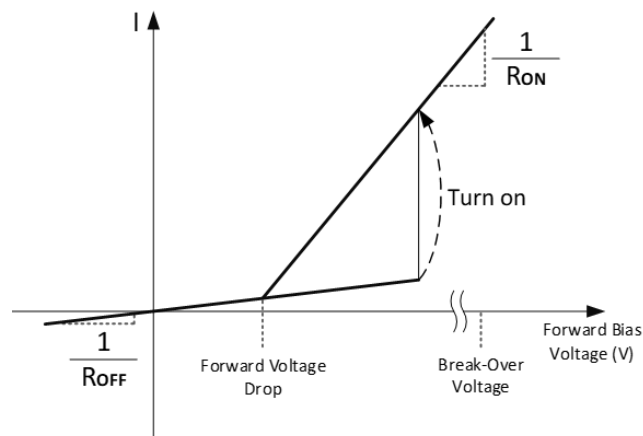


Figure 2: Thyristor V-I characteristic Curve

The Interpolation Algorithm is automatically invoked during all naturally commutated turn ON and turn OFF events (including Forward Break-Over), to calculate the exact instant of switching. Please note however, that the user is provided a choice to interpolate the incoming gate signal.

The extinction time is also represented. The thyristor therefore, will re-fire following a turn OFF if the Minimum Extinction Time parameter input has not elapsed before the forward voltage rises above the Forward Voltage Drop parameter input. This will occur even in the absence of a turn on signal.

NOTE: Reverse recovery time (i.e. the time for which a finite reverse current flows in the device, following a turn OFF) of the Thyristor is assumed zero. If the ON resistance is zero or smaller than the Switching Threshold value, the closed state will be modeled as an ideal short circuit.

### 1.3. GTO/IGBT/Transistor

The GTO, IGBT, and Transistor models are essentially the same. The GTO/IGBT/Transistor is usually turned ON and OFF by firing signals supplied to the gate terminal. An external control signal is required to generate the gate firing pulses.

The characteristics of the GTO/IGBT/Transistor are very similar to that of the Thyristor except that a GTO/IGBT/Transistor can be forced to turn OFF with a gate pulse of 0, while the device is forward biased and conducting current.

The V-I characteristic for the GTO/IGBT/Transistor model is shown in [Figure 3](#).

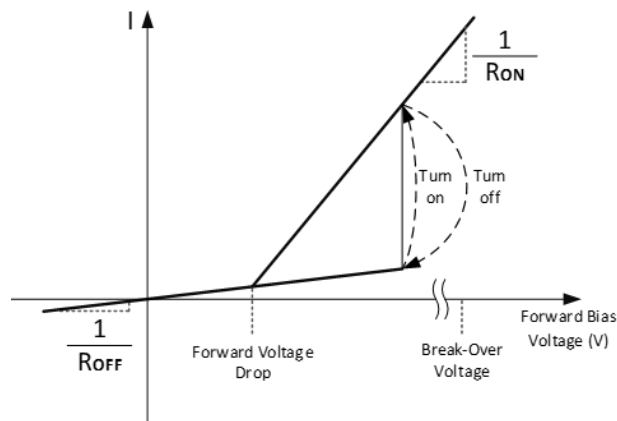


Figure 3: GTO, IGBT, and Transistor V-I characteristic Curve

The Interpolation Algorithm is automatically invoked during all naturally commutated turn ON and turn OFF events (including Forward Break-Over), to calculate the exact instant of switching. Please note however, that the user is provided a choice to interpolate the incoming gate signal.

NOTE: Reverse recovery time (i.e. the time for which a finite reverse current flows in the device, following a turn OFF) of the diode is assumed zero. If the ON resistance is zero or smaller than the Switching Threshold value, the closed state will be modeled as an ideal short circuit.

## 2. PSCAD/EMTDC EXAMPLE DESCRIPTION

### 2.1. Example 1

The purpose of this example is to demonstrate the V-I characteristic curve of the Thyristor and the diode implemented in PSCAD/EMTDC. The parameters of the thyristor in circuit 1.1, 1.2 and 1.3 and the diode in circuit 1.4 are shown in [Figure 4](#). The forward bias voltage across the thyristor and the diode is controlled by a DC voltage source with an initial ramp up rate of 1V/s.

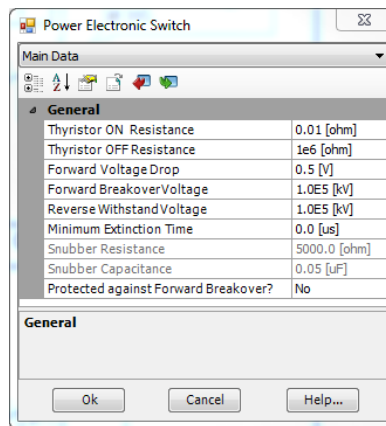
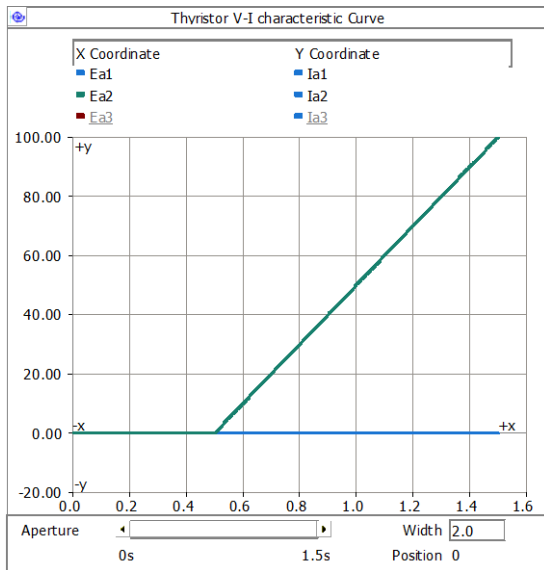
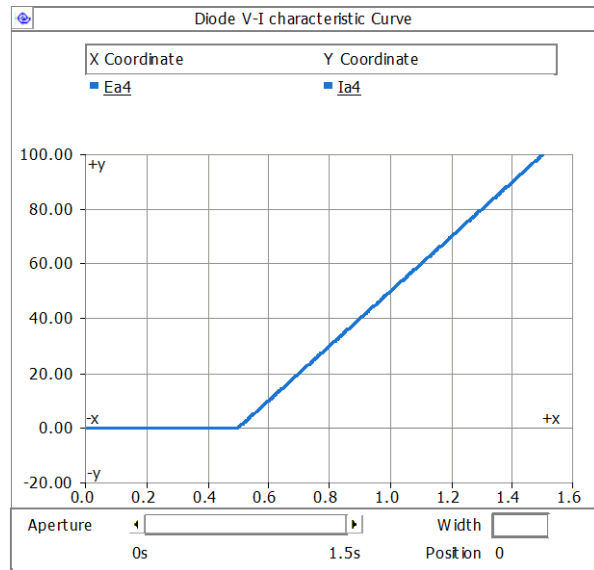


Figure 4: Thyristor and Diode Parameters

The thyristor in circuit 1.1 remains off during the simulation. The thyristor in circuit 1.2 remains on during the simulation. The thyristor in circuit 1.3 is in off state initially and a firing pulse is provided to the thyristor when the forward bias voltage reaches 1V. The blue curve in [Figure 4](#) shows the V-I characteristic when there is no firing pulse supplied to the thyristor. The green curve in [Figure 5](#) shows the V-I characteristic when the thyristor is on all the time, this curve is exactly the same with the V-I characteristic of the diode in circuit 1.4. The red curve in [Figure 6](#) shows the V-I characteristic transition when the thyristor turns on at 1V.



(a)



(b)

Figure 5: (a) Thyristor in off and on State (b) Diode in off and on state

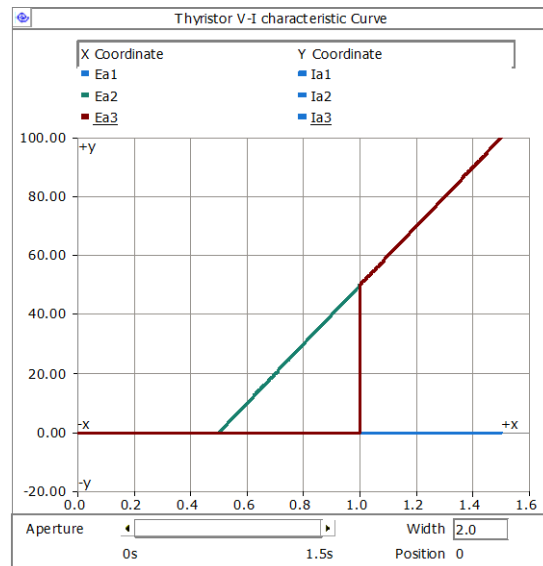


Figure 6: Thyristor off on Transition

## 2.2. Example 2

The purpose of this example is to demonstrate a single-phase diode bridge rectifier as shown in [Figure 7](#).

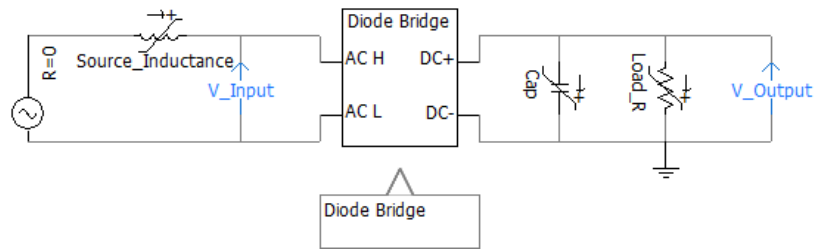


Figure 7: Single-Phase Diode Bridge Rectifier

The diode bridge rectifier is connected to a 230kV AC source with source inductance of 0.1mH. The output capacitance of the rectifier is 5mF, and output load resistance is 20ohm. [Figure 8](#) shows the input voltage of the rectifier and the DC voltage output.

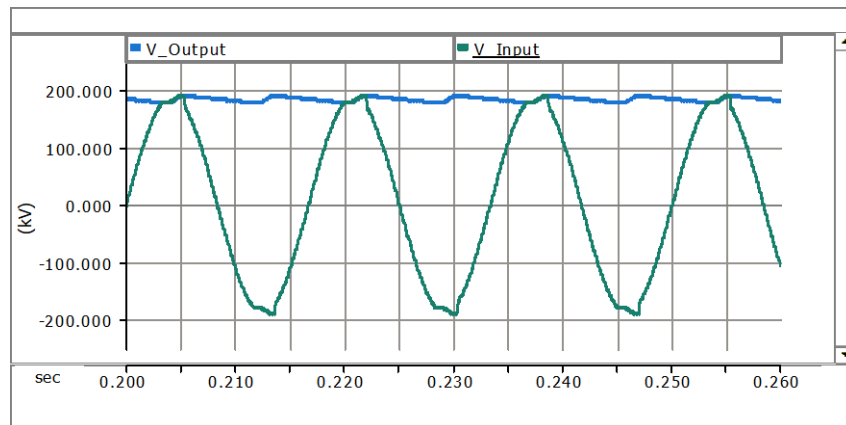


Figure 8: Diode Bridge Rectifier, Input and Output Voltage



### 2.3. Example 3

The purpose of this example is to demonstrate a simple application of IGBT switches, i.e. Buck and Boost Converter, as shown in [Figure 9](#) and [Figure 10](#). The Switching frequency of the converter is 2kHz. The converter inductor and capacitor are set to be 10mH and 5mF.

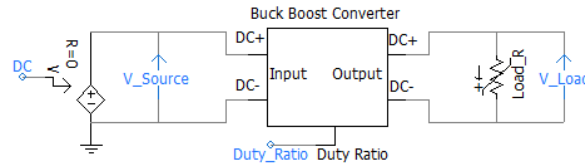


Figure 9: Buck and Boost Converter Example

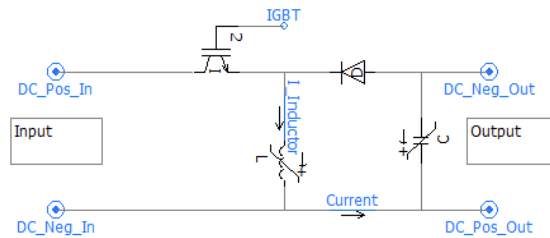


Figure 10: Buck and Boost Converter Schematic [1]

[Figure 11](#) shows the response of this simple buck-boost converter under different duty cycles.

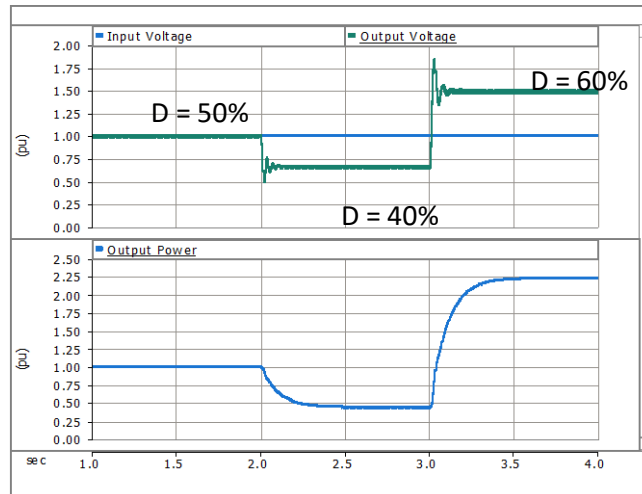


Figure 11: Input voltage, output voltage and output measurement

### 2.4. Example 4

The purpose of this example is to demonstrate a Series-Loaded Resonant DC-DC converter as shown in Figure 12 and Figure 13.

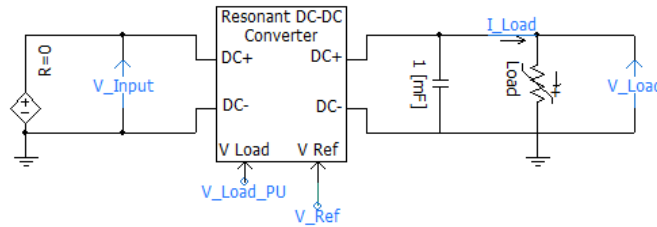


Figure 12: Series-Loaded Resonant DC-DC Converter Example

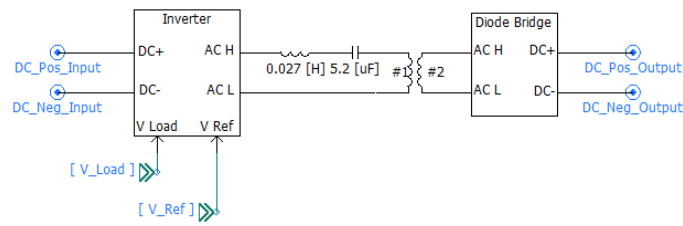


Figure 13: Series-Loaded Resonant DC-DC Converter Schematic

Figure 14 shows the response of this simple resonant converter under different voltage set points.

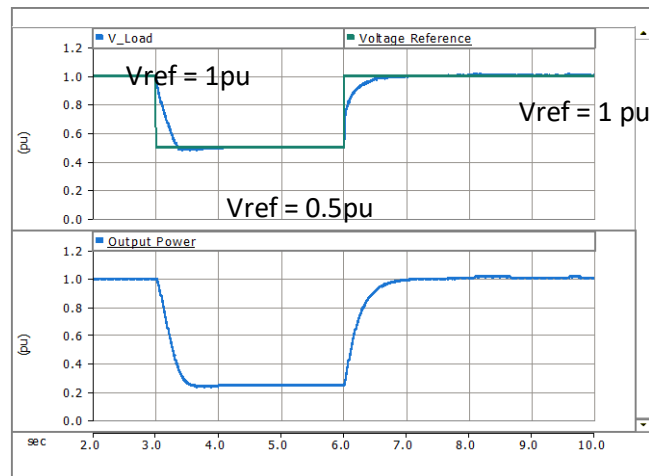


Figure 14: Voltage output, voltage set point and power output

### 2.5. Example 5

The purpose of this example is to demonstrate a thyristor based 6 pulse rectifier as shown in [Figure 15](#) and [Figure 16](#).

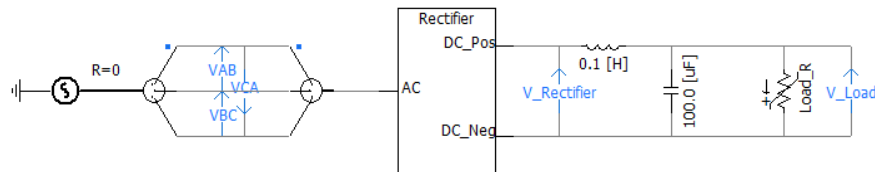


Figure 15: Thyristor Based 6 Pulse Rectifier example

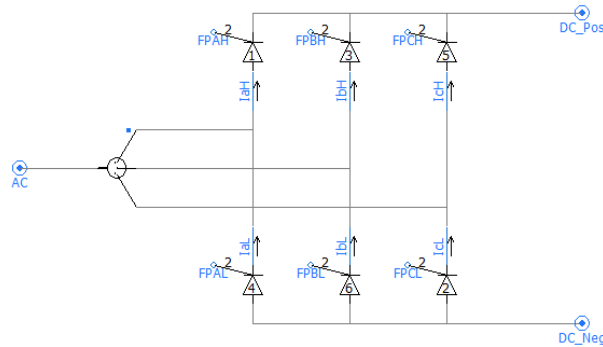


Figure 16: Thyristor Based 6 Pulse Rectifier Schematic

[Figure 17](#) and [Figure 18](#) show the response of a 6-pulse thyristor bridge under different firing angles.

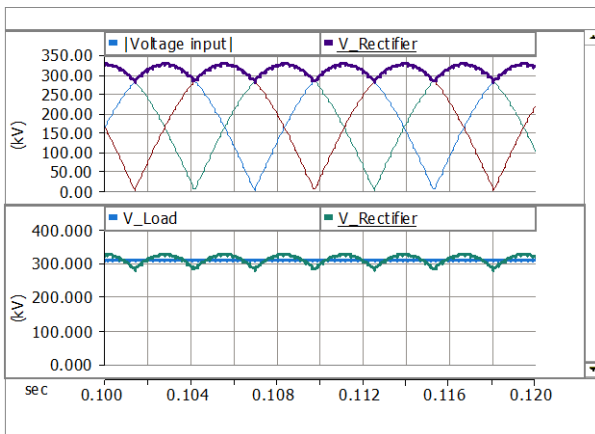


Figure 17: Angle  $\alpha = 0^\circ$

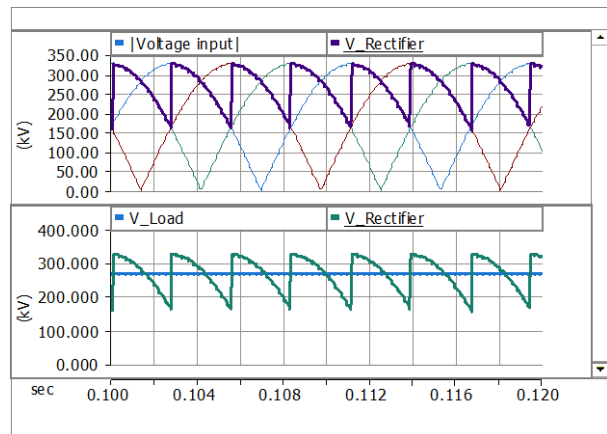


Figure 18: Angle  $\alpha = 30^\circ$

### 2.6. Example 6

The purpose of this example is to demonstrate an IGBT based 3 phase inverter with PWM firing pulse control as shown in [Figure 19](#) and [Figure 20](#).

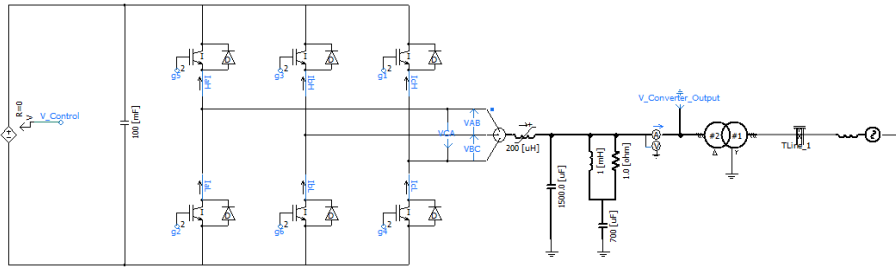


Figure 19: Two Level 3 phase inverter

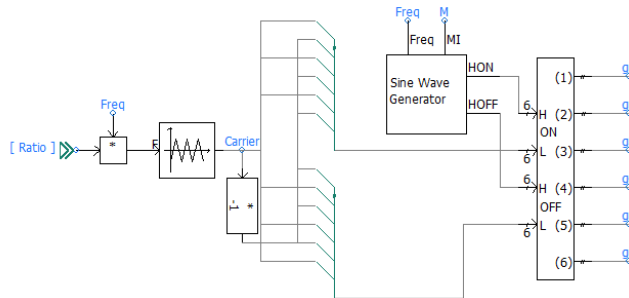


Figure 20: Interpolated Firing Pulse Generator

[Figure 21](#) shows the 3-phase inverter operation during steady-state.

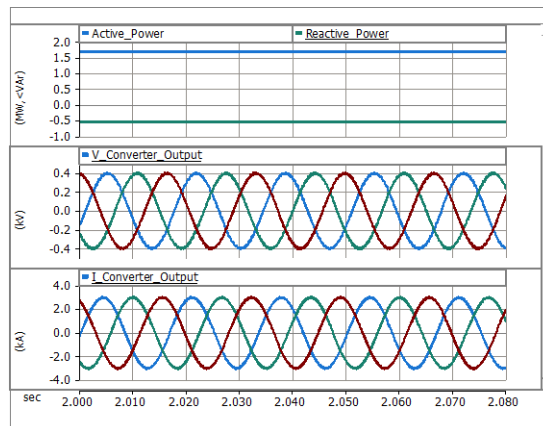


Figure 21: Inverter output power, voltage and current



### **3. REFERENCE**

- [1] Mohan, N., Undeland, T. M., & Robbins, W. P. (2007). Power electronics: Converters, applications, and design. New Delhi, India: John Wiley & Sons



DOCUMENT TRACKING

Rev.	Description	Date
0	Initial	30/Jan/2020