الكترونيات الطاقة

Lecture No. 4

دارة تقويم موجة كاملة أحادية الطور جسريه
Bridge Rectifier

ميكاترونيكس - سنة رابعة - فصل ثاني

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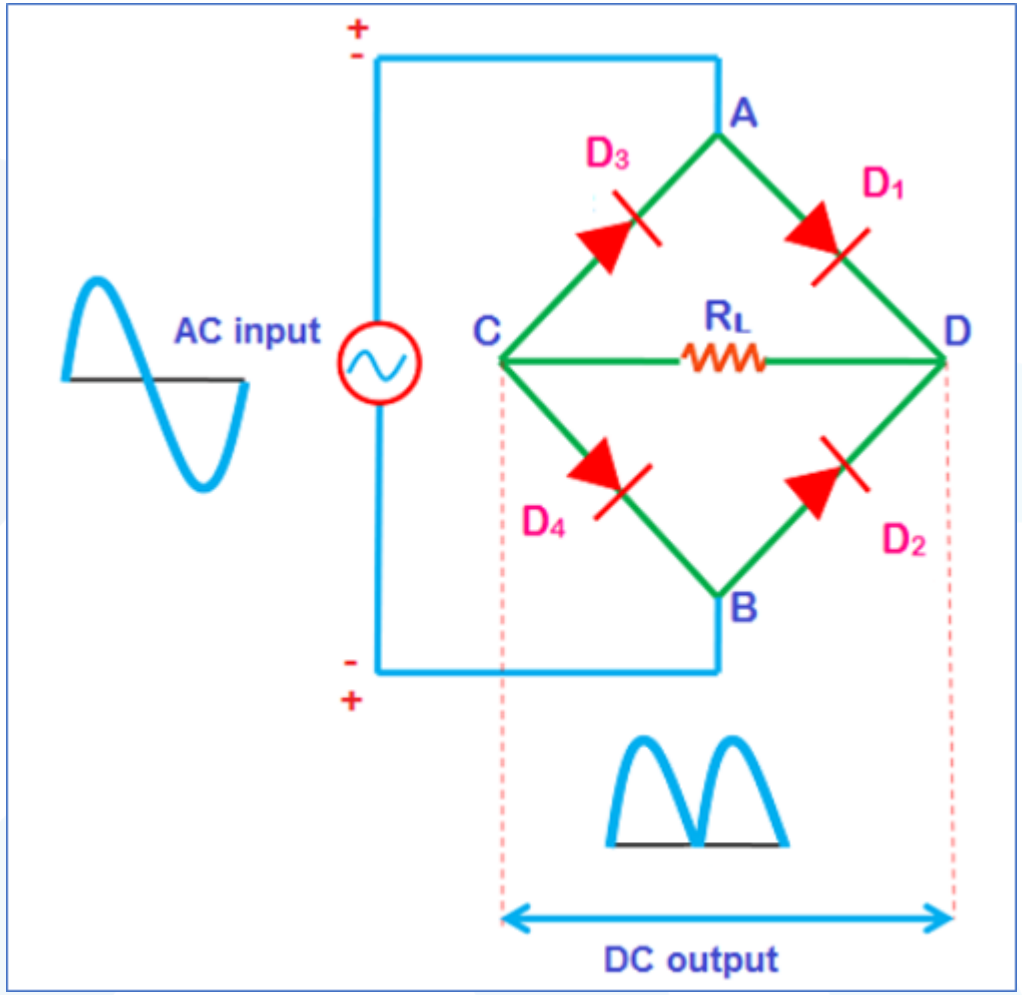
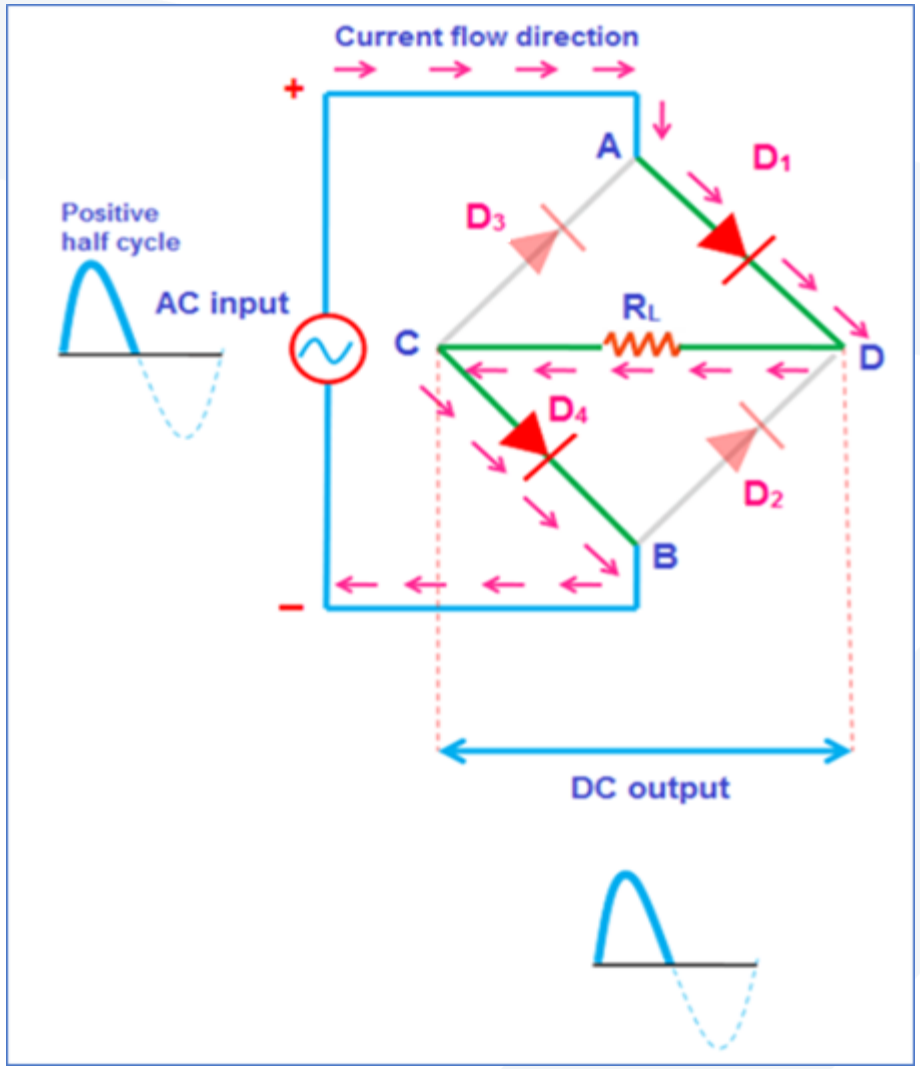
Ph.D. Degree in Mechatronics Engineering

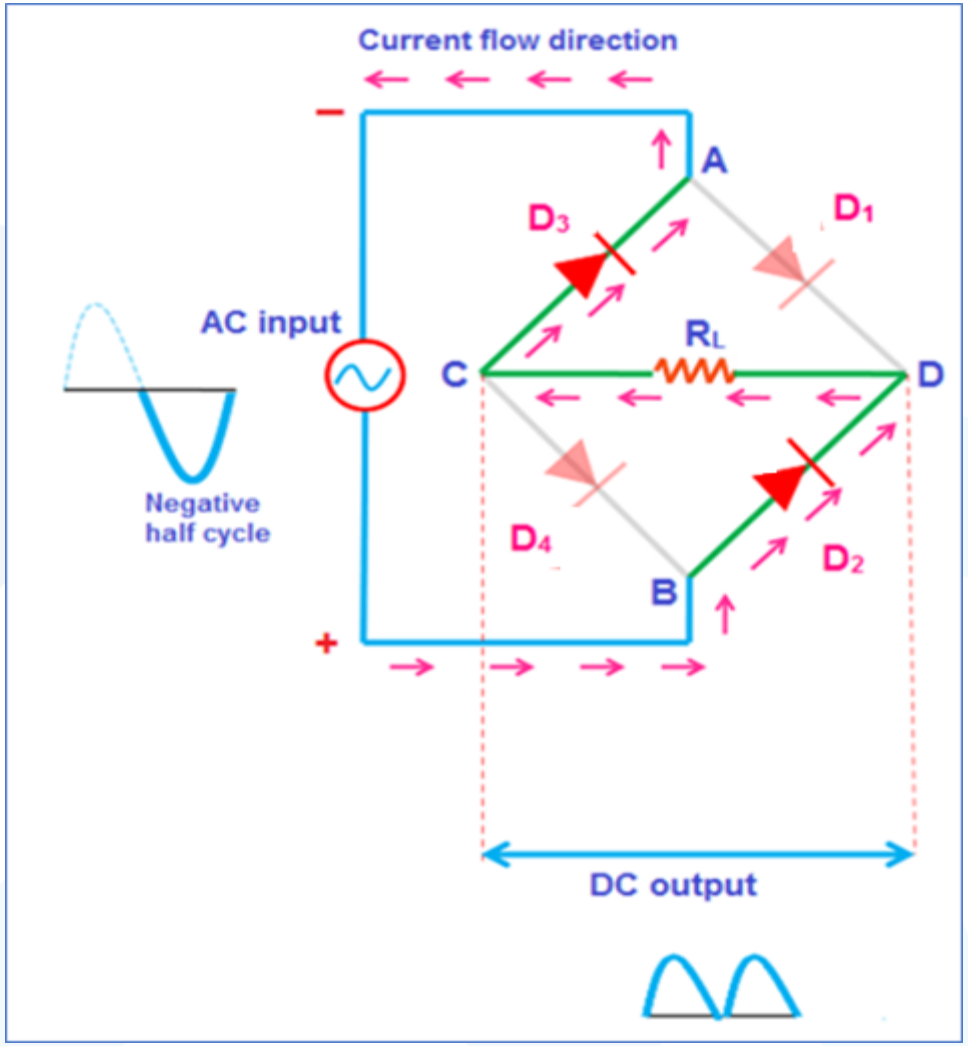
2023

- In half wave rectifier, only 1 half cycle is allowed and the remaining half cycle is blocked. As a result, nearly half of the applied power is wasted in half wave rectifier. In addition to this, the output current or voltage produced by half wave rectifier is not a pure DC but a pulsating DC which is not much useful.
- The main advantage of center tapped full wave rectifier is that it allows electric current during both positive and negative half cycles of the input AC signal. As a result, the DC output of the center tapped full wave rectifier is double of that of a half-wave rectifier. In addition to this, the DC output of center tapped full wave rectifier contains very fewer ripples. As a result, the DC output of the center tapped full wave rectifier is smoother than the half wave rectifier.
- the center tapped full wave rectifier has one drawback that is the center-tapped transformer used in it is very expensive and occupies large space. Also there is an average [mean] component of the source current.
- To cut this extra cost, scientists developed a new type of rectifier known as a bridge rectifier. In bridge rectifier, center tap is not required. If stepping down or stepping up of voltage is not required, then even the transformer can be eliminated in the bridge rectifier.

- The rectifier efficiency of a bridge rectifier is almost equal to the center tapped full wave rectifier.
- The bridge rectifier is made up of four diodes namely D_1, D_2, D_3, D_4 and load resistor R_L.
- The four diodes are connected in a closed loop (Bridge) configuration to efficiently convert the Alternating Current (AC) into Direct Current (DC).




Current flow direction
+
A
D1
D3
Positive
half cycle
AC input
RL
C
D
D4
D2
B
−
DC output


Current flow direction
−
A
D3
D1
AC input
RL
C
D
Negative
half cycle
D4
D2
B
+
DC output

جَامعة المَنارة
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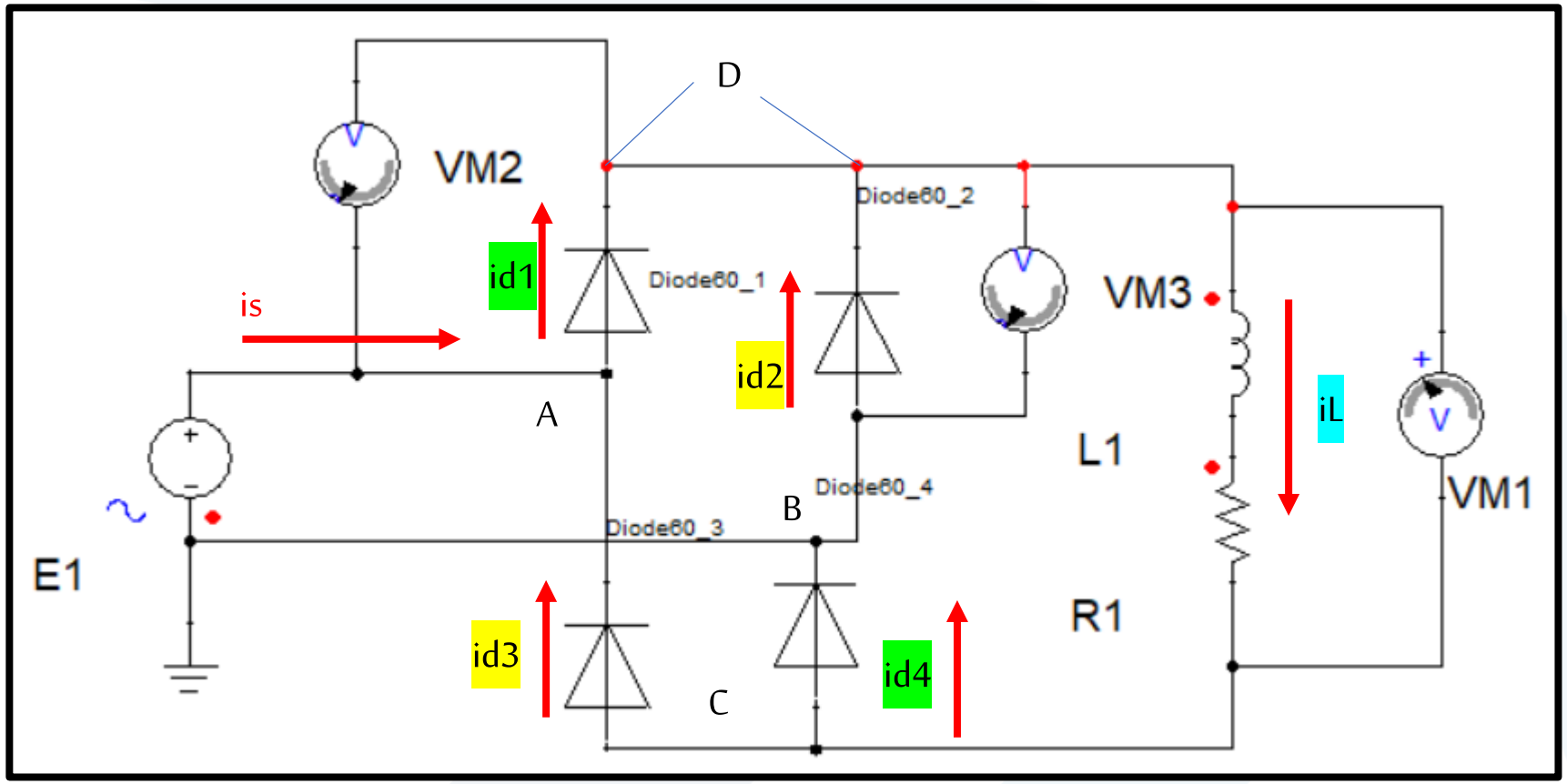
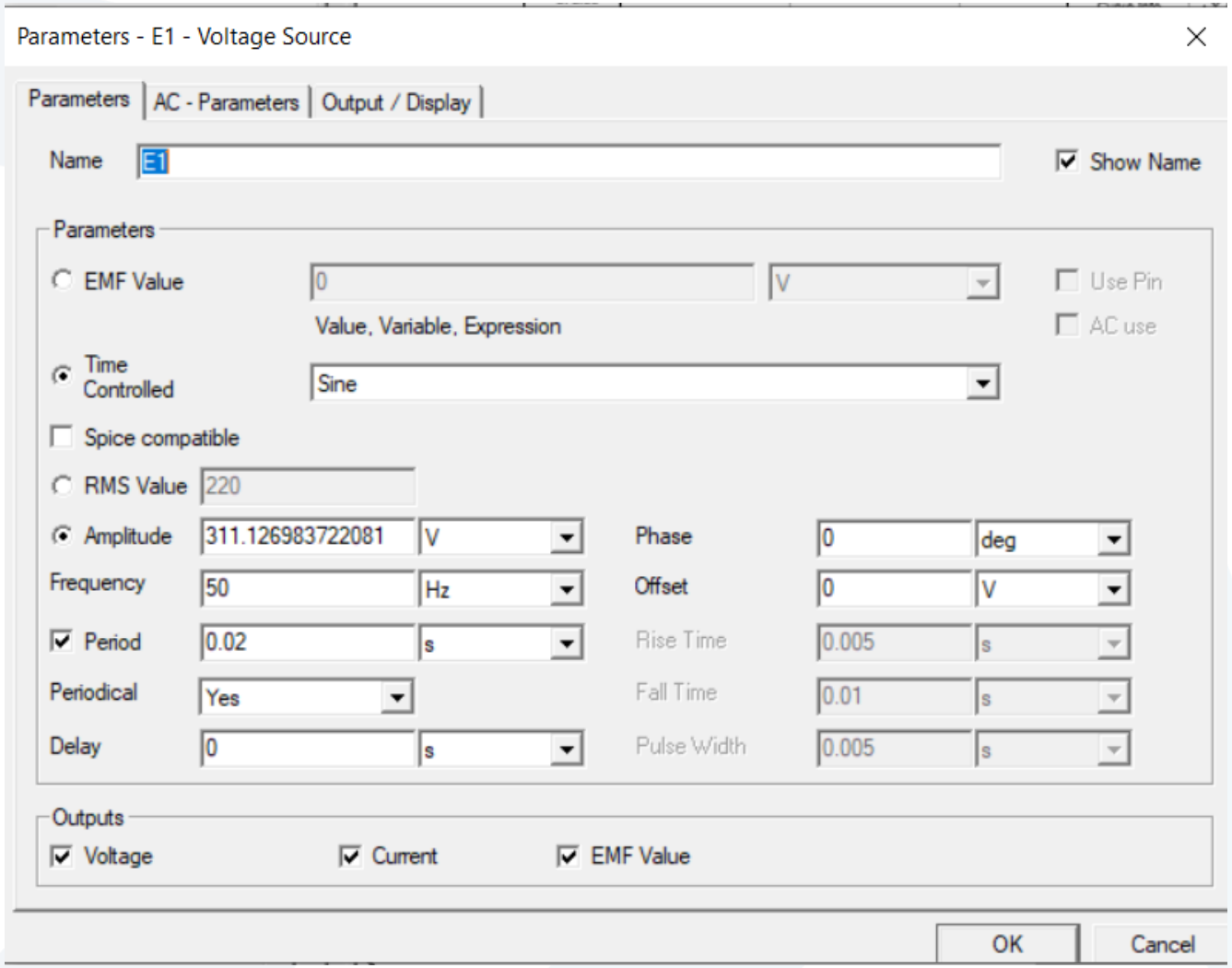
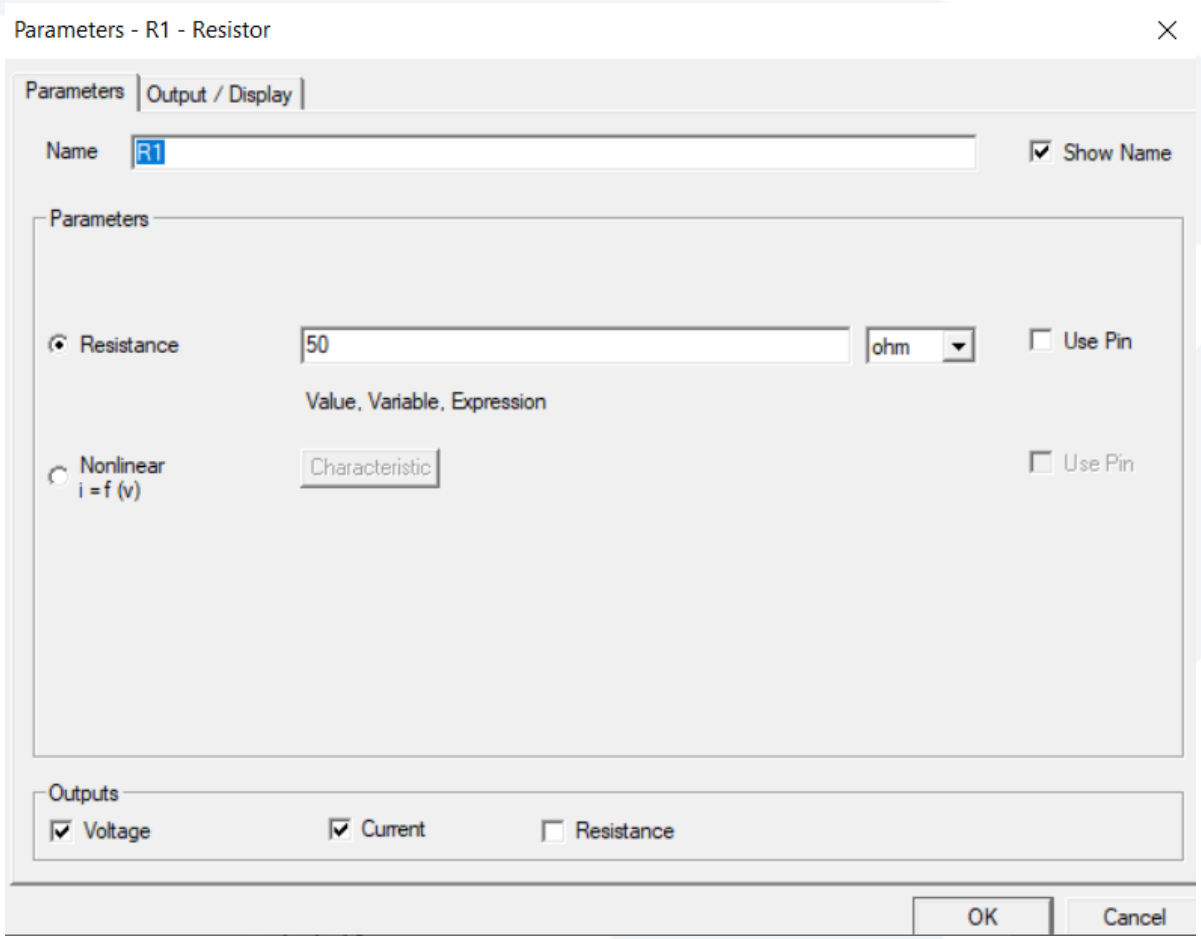
حمولة أومية صرفة

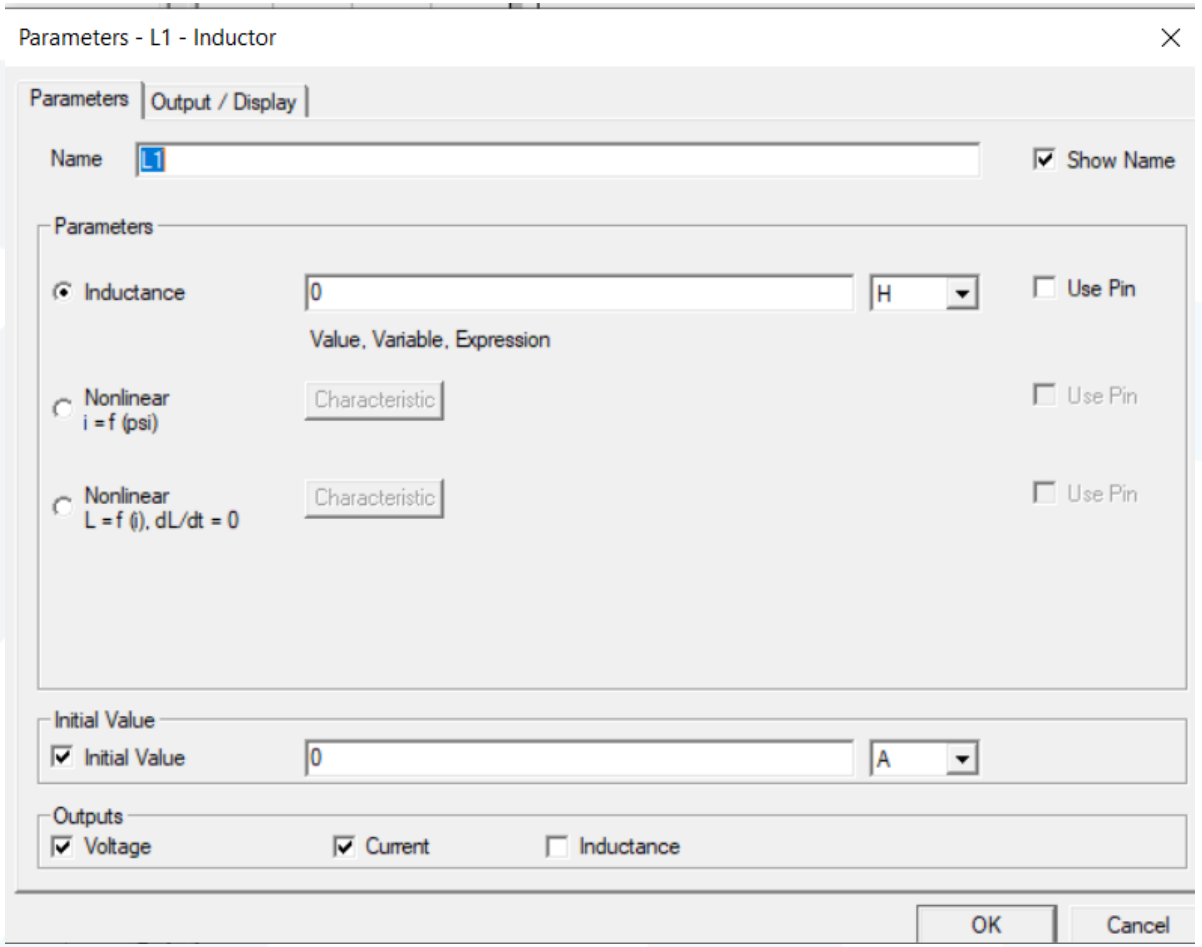


المنبع


Parameters - E1 - Voltage Source
Parameters
AC - Parameters
Output / Display
Name
E1
Show Name
Parameters
EMF Value
0
V
Use Pin
Value, Variable, Expression
AC use
Time Controlled
Sine
Spice compatible
RMS Value
220
Amplitude
311.126983722081
V
Phase
0
deg
Frequency
50
Hz
Offset
0
V
Period
0.02
s
Rise Time
0.005
s
Periodical
Yes
Fall Time
0.01
s
Delay
0
s
Pulse Width
0.005
s
Outputs
Voltage
Current
EMF Value
OK
Cancel

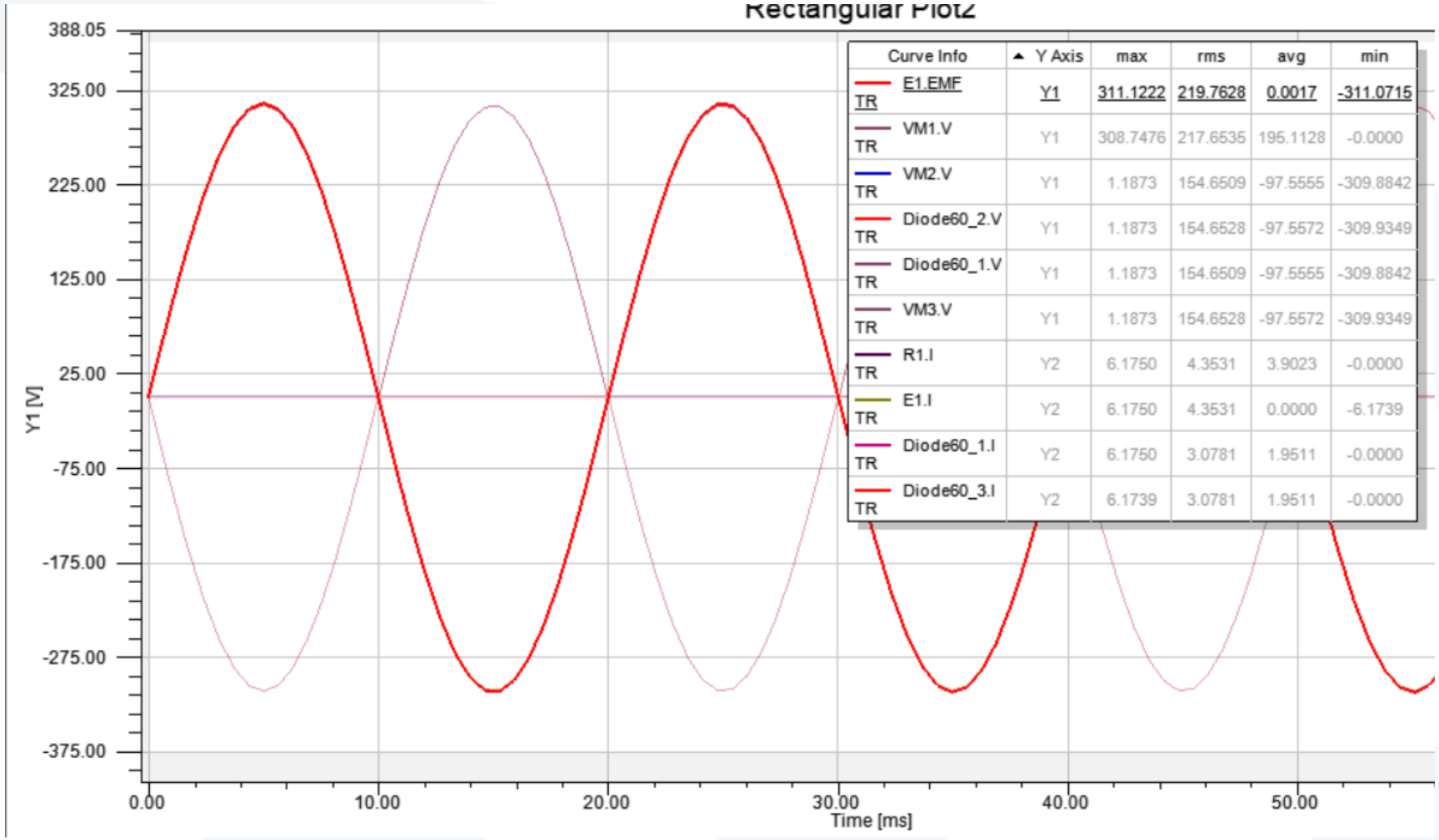
حمولة أومية صرفة





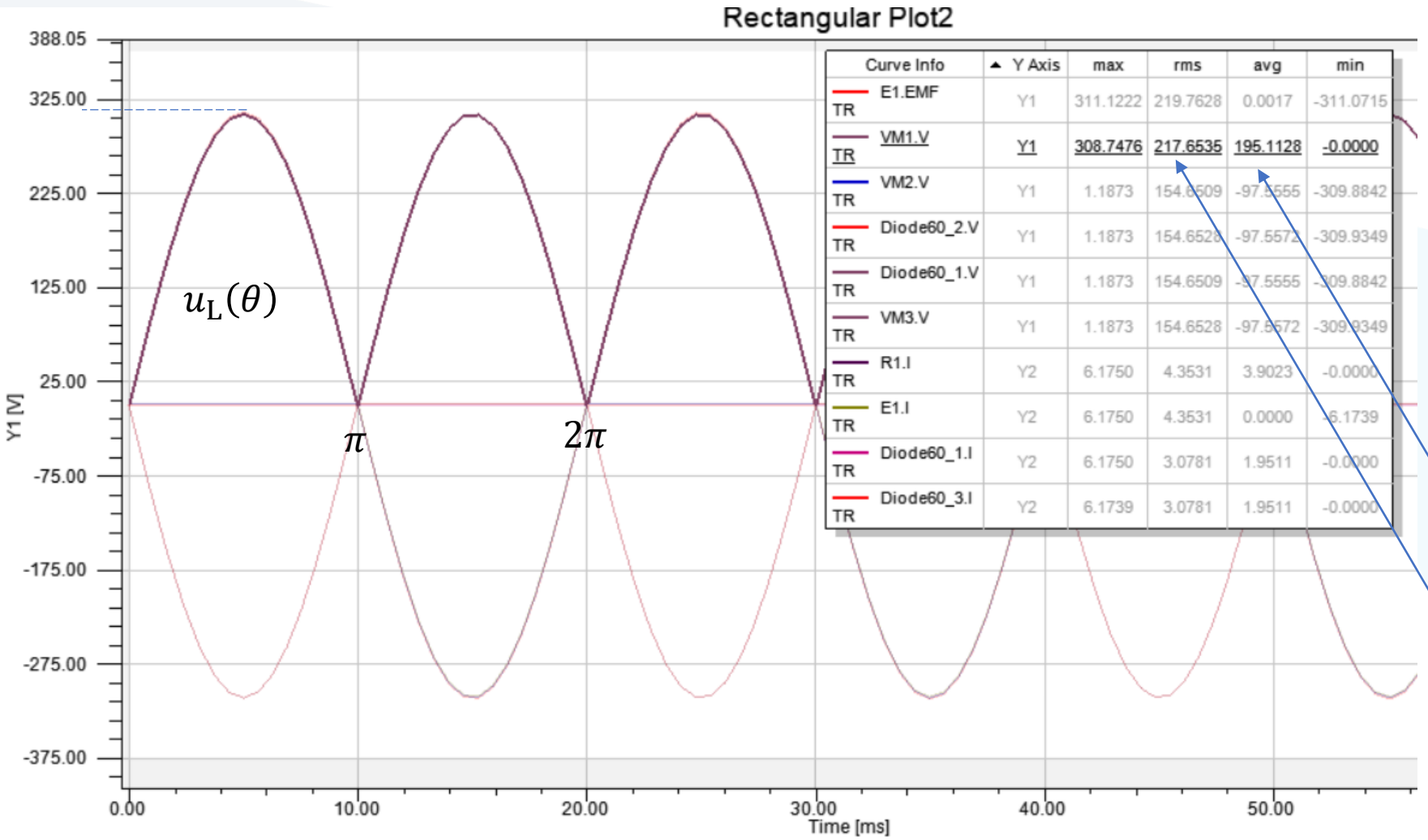
$$e_1 = u_1 = U_{2m} \sin(\theta) = \sqrt{2} U_{2rms} \sin(\theta)$$

جهد المنبع



جهد الحمل

U_{2m}



Curve Info	Y Axis	max	rms	avg	min
E1.EMF TR	Y1	311.1222	219.7628	0.0017	-311.0715
VM1.V TR	Y1	308.7476	217.6535	195.1128	-0.0000
VM2.V TR	Y1	1.1873	154.6509	-97.5555	-309.8842
Diode60_2.V TR	Y1	1.1873	154.6528	-97.5572	-309.9349
Diode60_1.V TR	Y1	1.1873	154.6509	-97.5555	-309.8842
VM3.V TR	Y1	1.1873	154.6528	-97.5572	-309.9349
R1.I TR	Y2	6.1750	4.3531	3.9023	-0.0000
E1.I TR	Y2	6.1750	4.3531	0.0000	-6.1739
Diode60_1.I TR	Y2	6.1750	3.0781	1.9511	-0.0000
Diode60_3.I TR	Y2	6.1739	3.0781	1.9511	-0.0000

ULav=0.9*220=198V

ULrms=220V

بارامترات جهد الحمل

يكون الجهد عبر الحمل U_L مكون من مركبة مستمرة DC بالإضافة الى تموج AC.

قيمة جهد الحمل الفعالة

$$U_{L_{rms}} = \sqrt{\frac{2}{2\pi}\int_0^{\pi} U_{2m}^2 \sin^2(\theta)\,d\theta}$$

$$U_{L_{rms}} = \sqrt{\frac{2U_{2m}^2}{4\pi}\int_0^{\pi} [1-\cos 2\theta]\,d\theta}$$

$$U_{L_{rms}} = \sqrt{\frac{2U_{2m}^2}{4\pi}\left[\theta - \frac{1}{2}\sin 2\theta\right]_0^{\pi}}$$

$$U_{L_{rms}} = \sqrt{\frac{2U_{2m}^2}{4\pi}\left[\pi - \frac{1}{2}\sin 2\pi - 0 + \frac{1}{2}\sin 0\right]} = \frac{\sqrt{2}U_{2m}}{2} = U_{2rms} = 220v$$

قيمة جهد الدخل الفعّالة

$$U_{L_{av}} = \frac{2}{2\pi}\left[\int_0^{\pi} U_{2m}\sin(\theta)\,d\theta\right]$$

$$U_{L_{av}} = \frac{2U_{2m}}{2\pi}\left[-\cos\theta\right]_0^{\pi} = \frac{2U_{2m}}{2\pi}[1+1]$$

$$U_{L_{av}} = \frac{2U_{2m}}{\pi} = \frac{2\sqrt{2}}{\pi}U_{2rms} = 0.9U_{2rms} = 198v$$

قيمة جهد الحمل المقوم المتوسطة

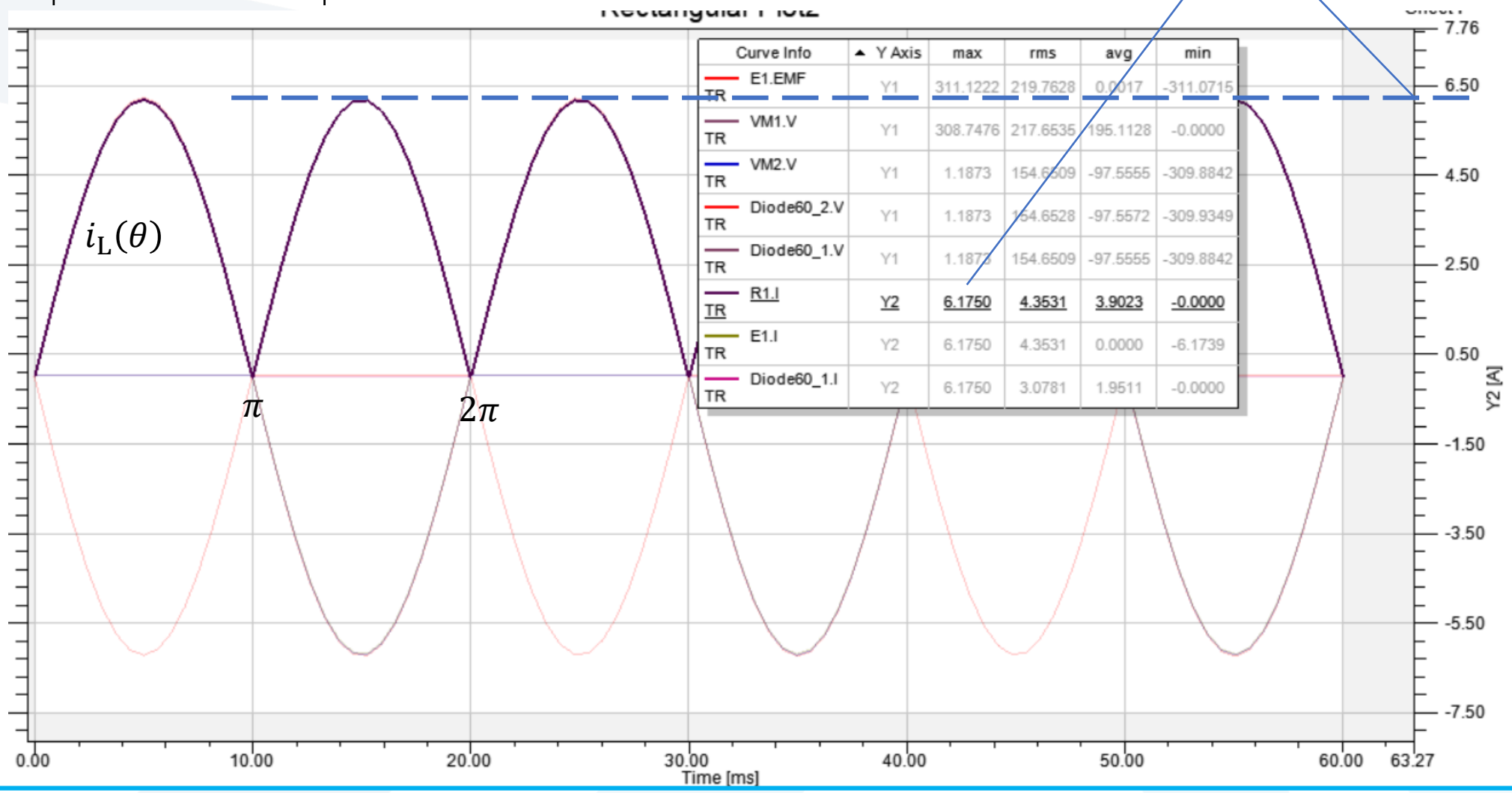
قيمة جهد الدخل الفعّالة

العلاقة السابقة تربط قيمة جهد الدخل الفعّالة وقيمة جهد الحمل المتوسطة

$$i_L = \left|\frac{U_{2m}}{R}\sin(\theta)\right| = \left|\frac{\sqrt{2}U_{2rms}}{R}\sin(\theta)\right| = \left|I_{2m}\sin(\theta)\right|$$

$$I_{2m} = \frac{U_{2m}=311v}{R=50ohm} = 6.22A$$

تيار الحمل



بارامترات تيار الحمل

يكون التيار عبر الحمل i_L مكون من مركبة مستمرة DC بالإضافة الى تموج AC.

$$I_{L_{av}} = \frac{2}{2\pi}\left[\int_0^{\pi} \frac{U_{2m}}{R}\sin(\theta)\,d\theta\right]$$

$$I_{L_{av}} = \frac{2\sqrt{2}}{\pi R}U_{2rms} = 0.9\frac{U_{2rms}}{R} = 0.9\frac{220}{50} = 3.96A$$

قيمة تيار الحمل المقوم المتوسطة

قيمة جهد الدخل الفعّالة

قيمة تيار الحمل الفعالة

$$I_{L_{rms}} = \sqrt{\frac{2}{2\pi}\int_0^{\pi} \frac{U_{2m}^2}{R^2}\sin^2(\theta)\,d\theta}$$

قيمة جهد الدخل الفعّالة

قيمة جهد الحمل الفعّالة

$$I_{L_{rms}} = \frac{\sqrt{2}U_{2m}}{2R} = \frac{U_{2rms}}{R} = \frac{U_{L_{rms}}}{R} = \frac{220v}{50\Omega} = 4.4A$$

Form factor

Form factor is defined as the ratio of RMS value to the DC value

F.F = RMS value / DC value

$$\frac{I_{L_{rms}}}{I_{L_{av}}} = \frac{\frac{U_{2rms}}{R}}{\frac{2\sqrt{2}}{\pi R}U_{2rms}} = \frac{\pi}{2\sqrt{2}} = 1.11$$

بنسب قيمتي التيار الفعّالة والمتوسطة إلى بعضها تنتج العلاقة التالية:

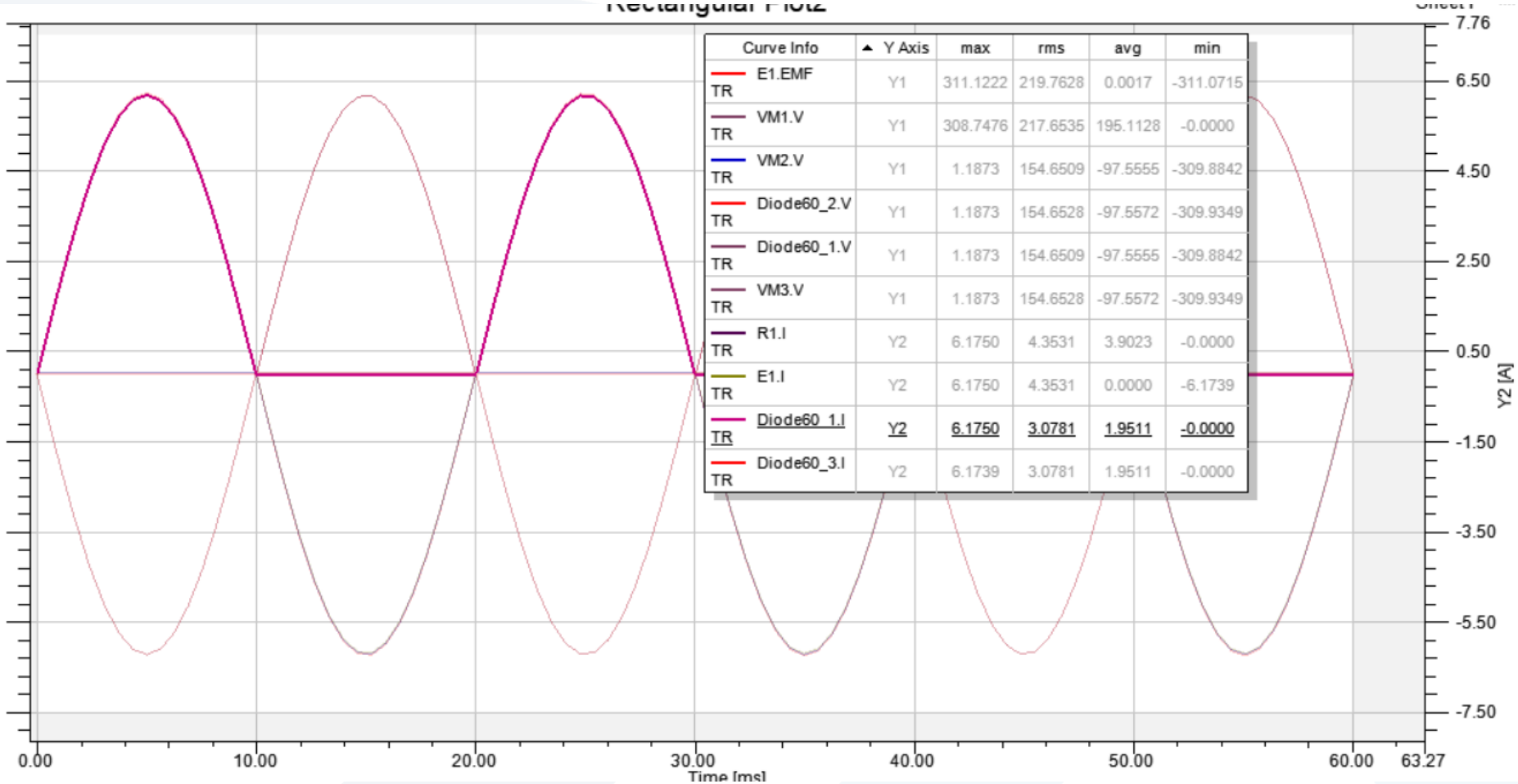
Ripples factor

- Ripples factor = rms value of AC component of the output voltage / DC component of the output voltage
- The ripple factor is also simply defined as the ratio of ripple voltage to the DC voltage
- Ripple factor = Ratio of ripple voltage / DC voltage.
- The ripple factor should be kept as minimum as possible to construct a good rectifier.
- The ripple factor is given as:

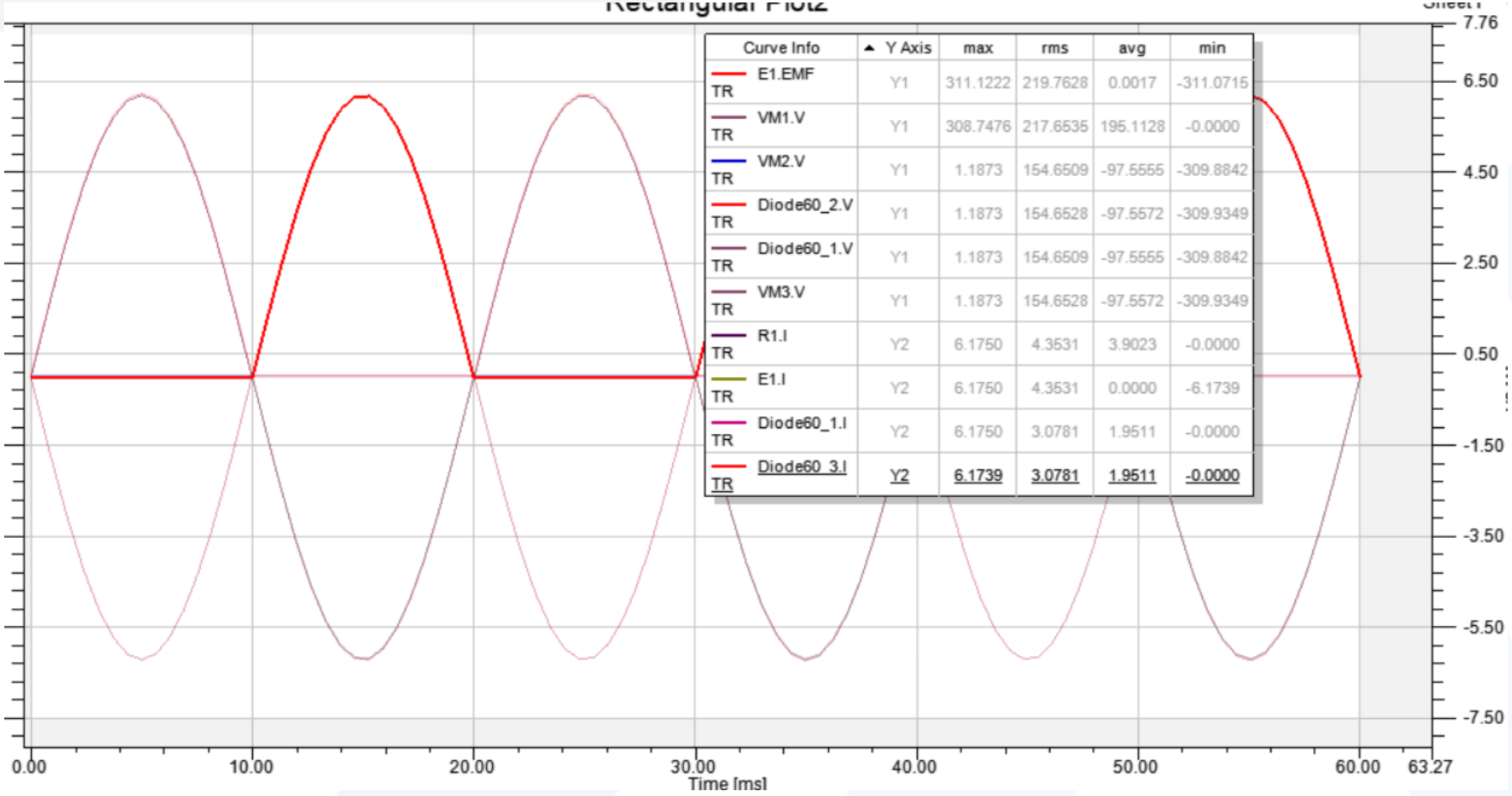
$$\gamma = \sqrt{\left(\frac{U_{L_{rms}}}{U_{L_{av}}}\right)^2 - 1} = \sqrt{\left(\frac{U_{2rms}}{\frac{2\sqrt{2}}{\pi}U_{2rms}}\right)^2} - 1 = \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1} = 0.48$$

- The unwanted ripple present in the output along with the DC voltage is 48% of the DC magnitude.

تيار الديود الأول والرابع



تيار الديود الثالث والثاني



بارامترات تيار الديود

$$I_{D_{av}} = \frac{1}{2\pi}\left[\int_0^{\pi} \frac{U_{2m}}{R}\sin(\theta)\,d\theta\right]$$

قيمة تيار الحمل المقوم المتوسطة

$$I_{D_{av}} = \frac{\sqrt{2}}{\pi R}U_{2rms} = 0.45\frac{U_{2rms}}{R} = \frac{I_{L_{av}}}{2} = 1.98A$$

قيمة تيار الديود المتوسطة

قيمة جهد الدخل الفعّالة

قيمة تيار الديود الفعالة

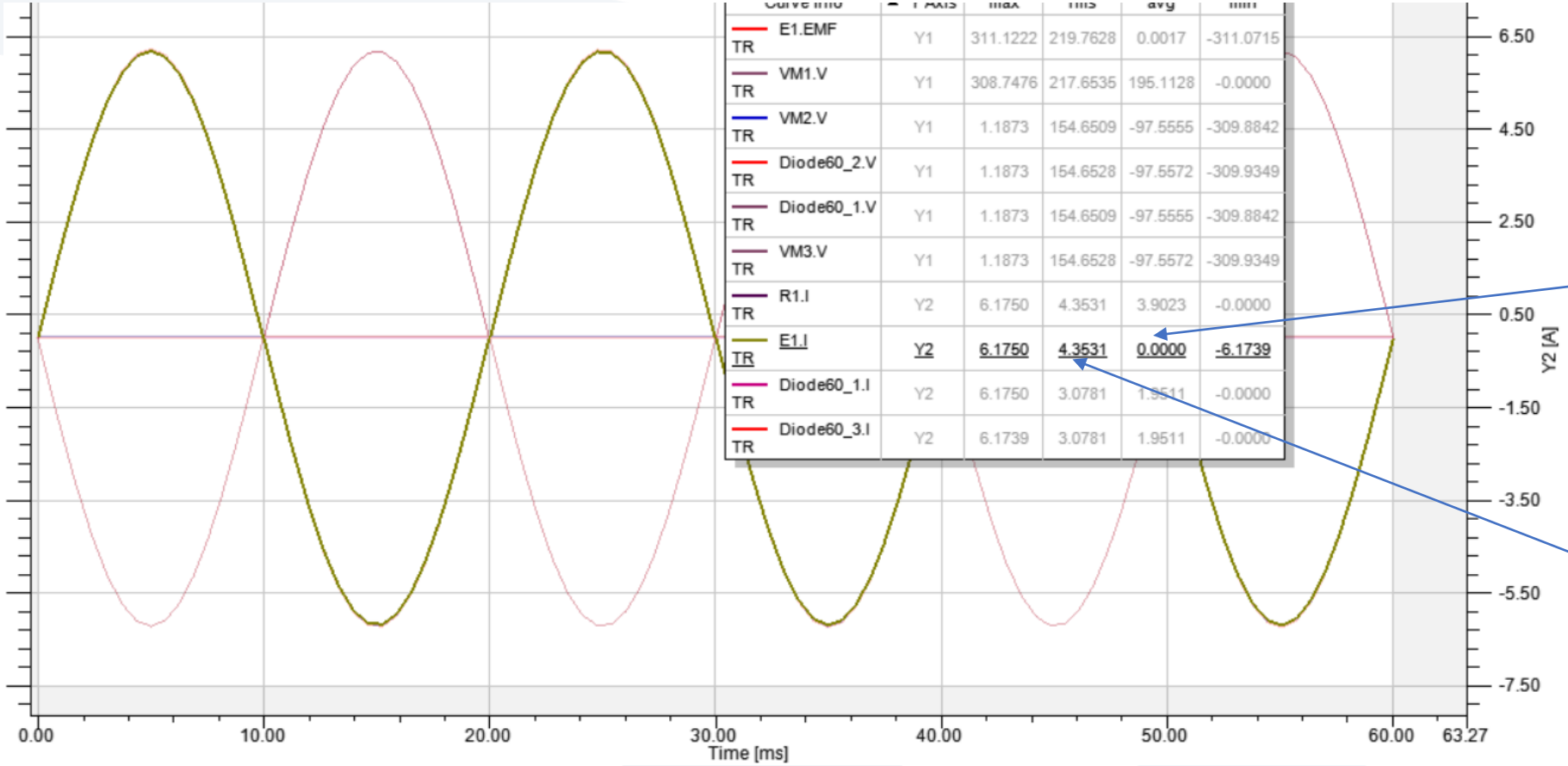
$$I_{D_{rms}} = \sqrt{\frac{1}{2\pi}\int_0^{\pi}\frac{U_{2m}^2}{R^2}\sin^2(\theta)\,d\theta}$$

قيمة جهد الدخل الفعّالة

قيمة جهد الحمل الفعّالة

$$I_{D_{rms}} = \frac{U_{2m}}{2R} = \frac{U_{2rms}}{\sqrt{2}R} = \frac{U_{L_{rms}}}{\sqrt{2}R} = 3.11A$$

تيار المنبع



تيار المنبع قيمة متوسطة

$$I_{S_{av}} = 0V$$

تيار المنبع قيمة فعالة كونها موجة جيبية صافية

$$I_{S_{rms}} = \frac{I_{S_m}}{\sqrt{2}} = \frac{\frac{U_{2m}}{R}}{\sqrt{2}} = \frac{U_{2rms}}{R} = \frac{\frac{311}{50}}{\sqrt{2}} = 4.39A$$

Rectifier efficiency

- Rectifier efficiency is defined as the ratio of output DC power to the input AC power.
- The rectifier efficiency of a full wave rectifier is 81.5%.

$$P_{out}(DC) = I_{L_{av}}^2 R = 3.96^2 * 50[W] = 784$$

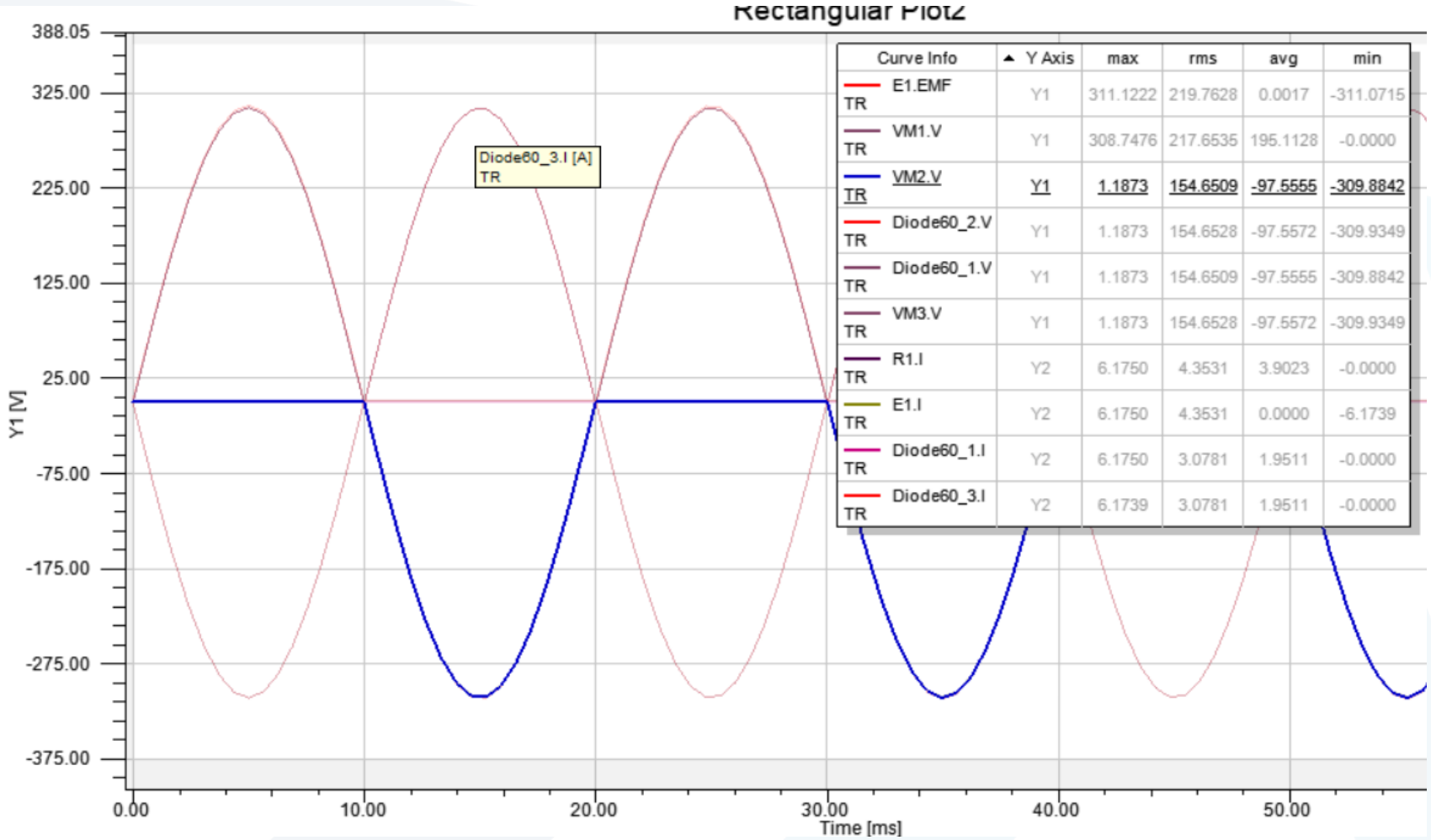
$$P_{in}(AC) = I_{S_{rms}}^2 R = 4.4^2 * 50[W] = 968[W]$$

$$P_{in}(AC) = I_{S_{rms}} U_{S_{rms}} = 4.4 * 220[W] = 968[W]$$

$$\eta = \frac{P_{out}(DC)}{P_{in}(AC)} \simeq 81\%$$

Peak inverse voltage (PIV)

جهد الديود الأول



Curve Info	Y Axis	max	rms	avg	min
E1.EMF TR	Y1	311.1222	219.7628	0.0017	-311.0715
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E1.I TR	Y2	6.1750	4.3531	0.0000	-6.1739
Diode60_1.I TR	Y2	6.1750	3.0781	1.9511	-0.0000
Diode60_3.I TR	Y2	6.1739	3.0781	1.9511	-0.0000

$VD1 = e1$

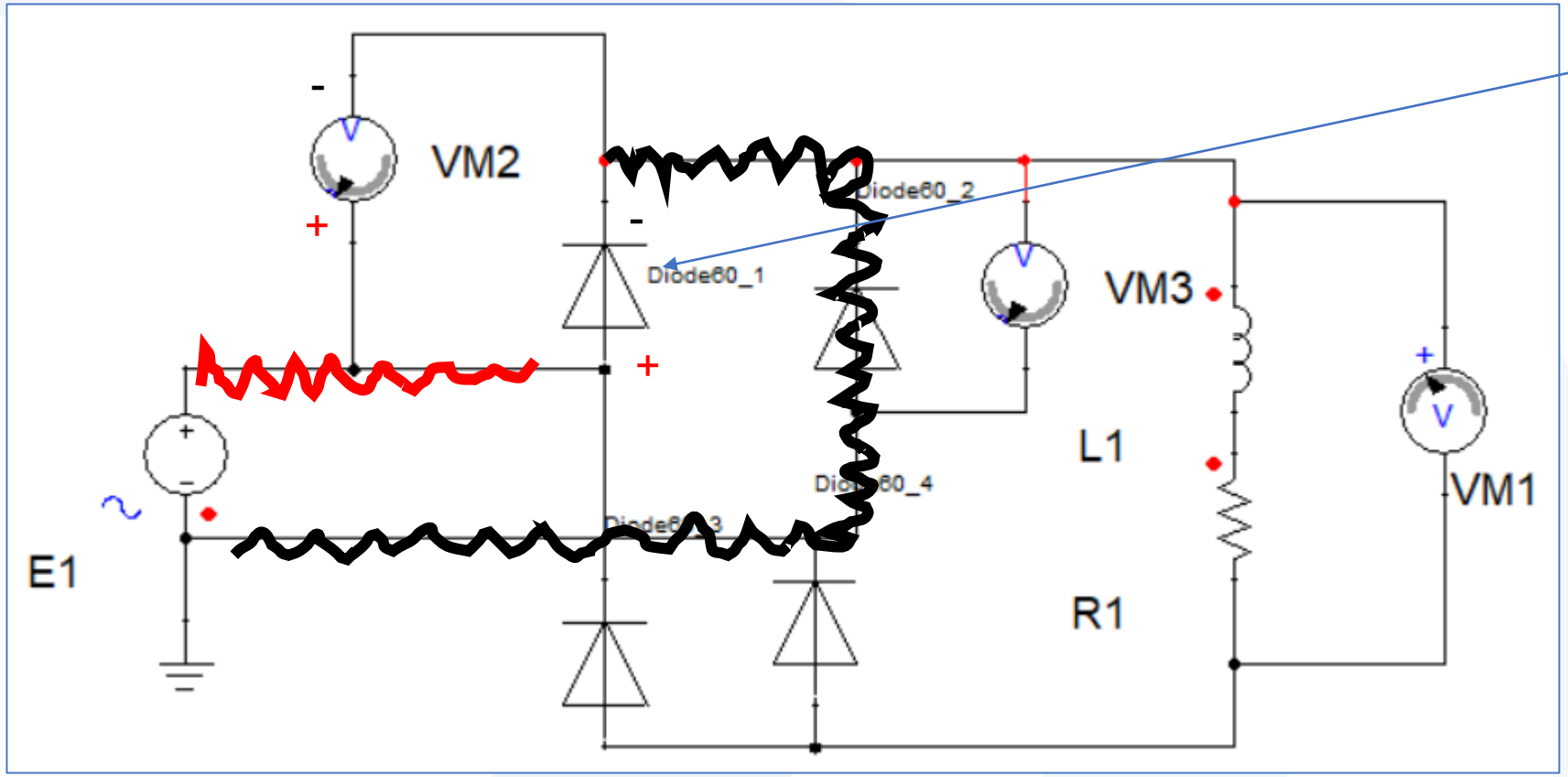
في نصف الموجة الثاني الديود الأول انحياز عكسي بينما الديود الثاني انحياز أمامي

$VD1 = 0$

في نصف الموجة الأول الديود الأول انحياز أمامي

Peak inverse voltage (PIV)

جهد الديود الأول



$VD1 = e1$

في نصف الموجة الثاني الديود الأول انحياز عكسي بينما الديود الثاني انحياز أمامي

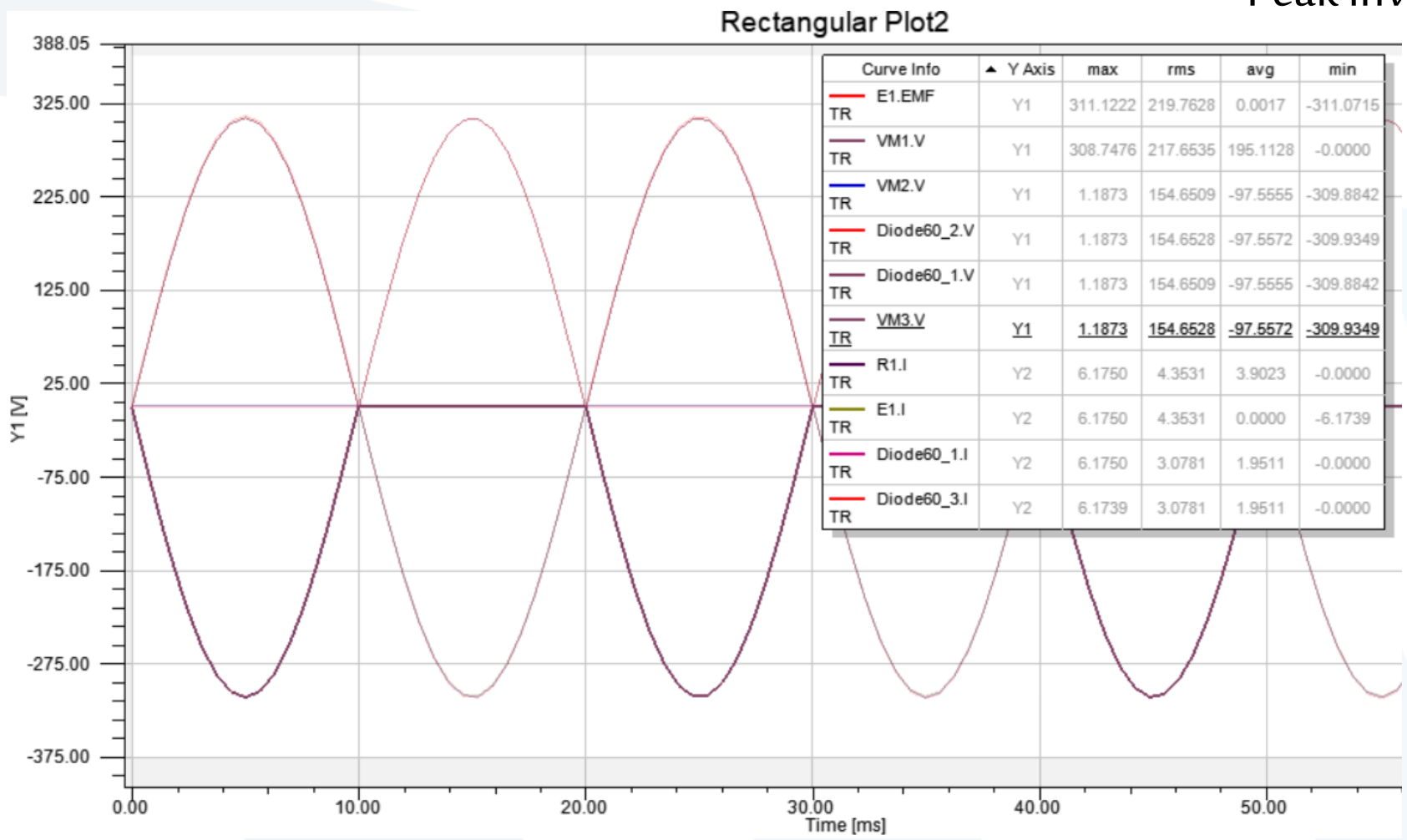
$VD1 = 0$

في نصف الموجة الأول الديود الأول انحياز أمامي

$$V_{DR_{MAX}} = -U_{2m}$$

جهد الديود الثاني

Peak inverse voltage (PIV)



$VD2 = -e1$

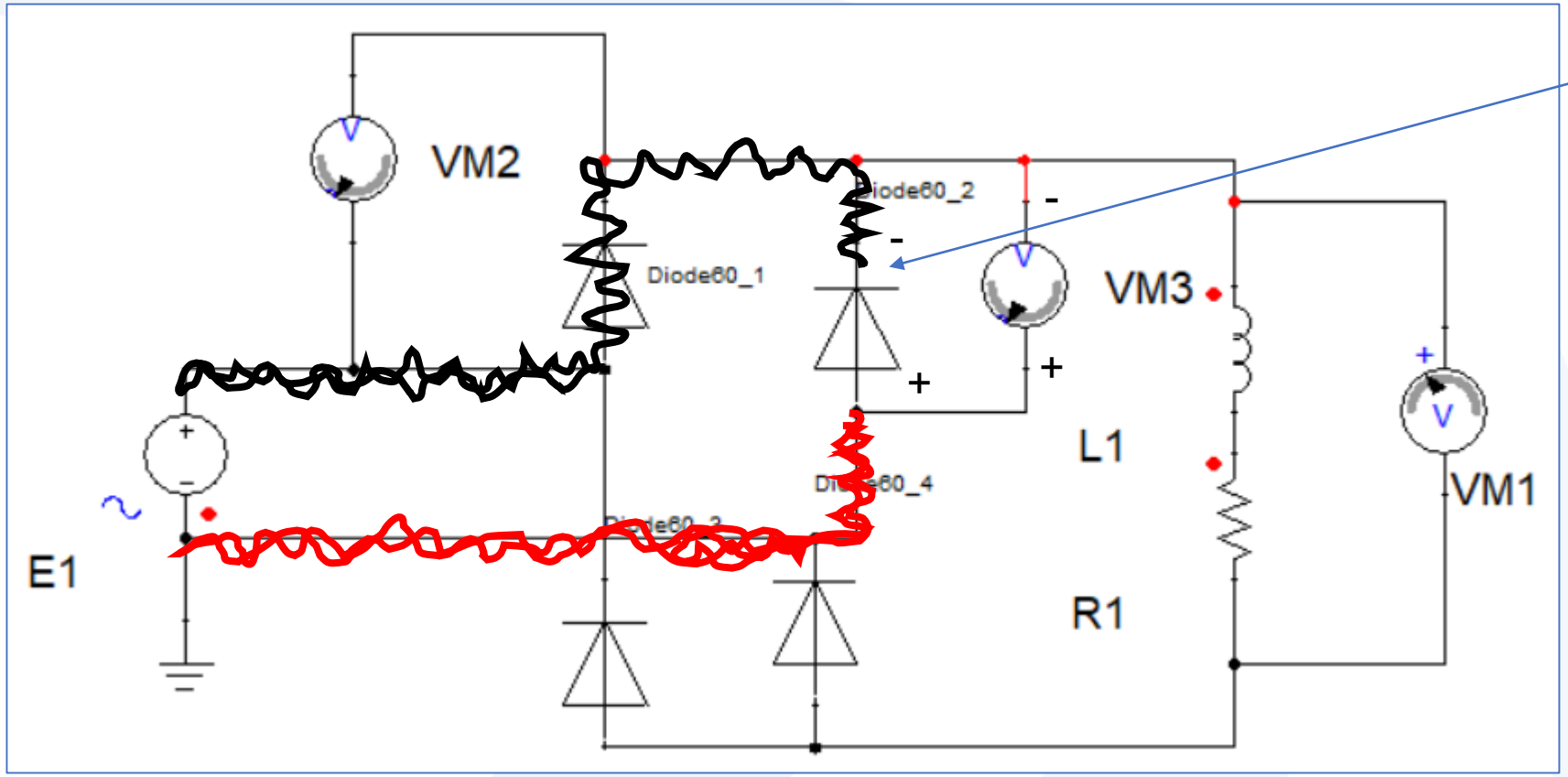
في نصف الموجة الأول الديود الثاني انحياز عكسي والديود الأول انحياز أمامي

$VD2 = 0$

في نصف الموجة الثاني الديود الثاني انحياز أمامي

جهد الديود الثاني

Peak inverse voltage (PIV)



$$VD2 = -e1$$

في نصف الموجة الأول
الديود الثاني انحياز عكسي
والديود الأول انحياز أمامي

$$VD2 = 0$$

في نصف الموجة الثاني
الديود الثاني انحياز أمامي

$$V_{DR_{MAX}} = -U_{2m}$$

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المنبع الأول

جهد الحمل

جهد الديود الأول

جهد الديود الثاني

جهد الديود الأول

جهد الديود الثاني

تيار الحمل

تيار المنبع

تيار الديود الأول

تيار الديود الثالث

Curve Info	Y Axis	max	rms	avg	min
E1.EMF TR	Y1	311.1222	219.7628	0.0017	-311.0715
VM1.V TR	Y1	308.7476	217.6535	195.1128	-0.0000
VM2.V TR	Y1	1.1873	154.6509	-97.5555	-309.8842
Diode60_2.V TR	Y1	1.1873	154.6528	-97.5572	-309.9349
Diode60_1.V TR	Y1	1.1873	154.6509	-97.5555	-309.8842
VM3.V TR	Y1	1.1873	154.6528	-97.5572	-309.9349
R1.I TR	Y2	6.1750	4.3531	3.9023	-0.0000
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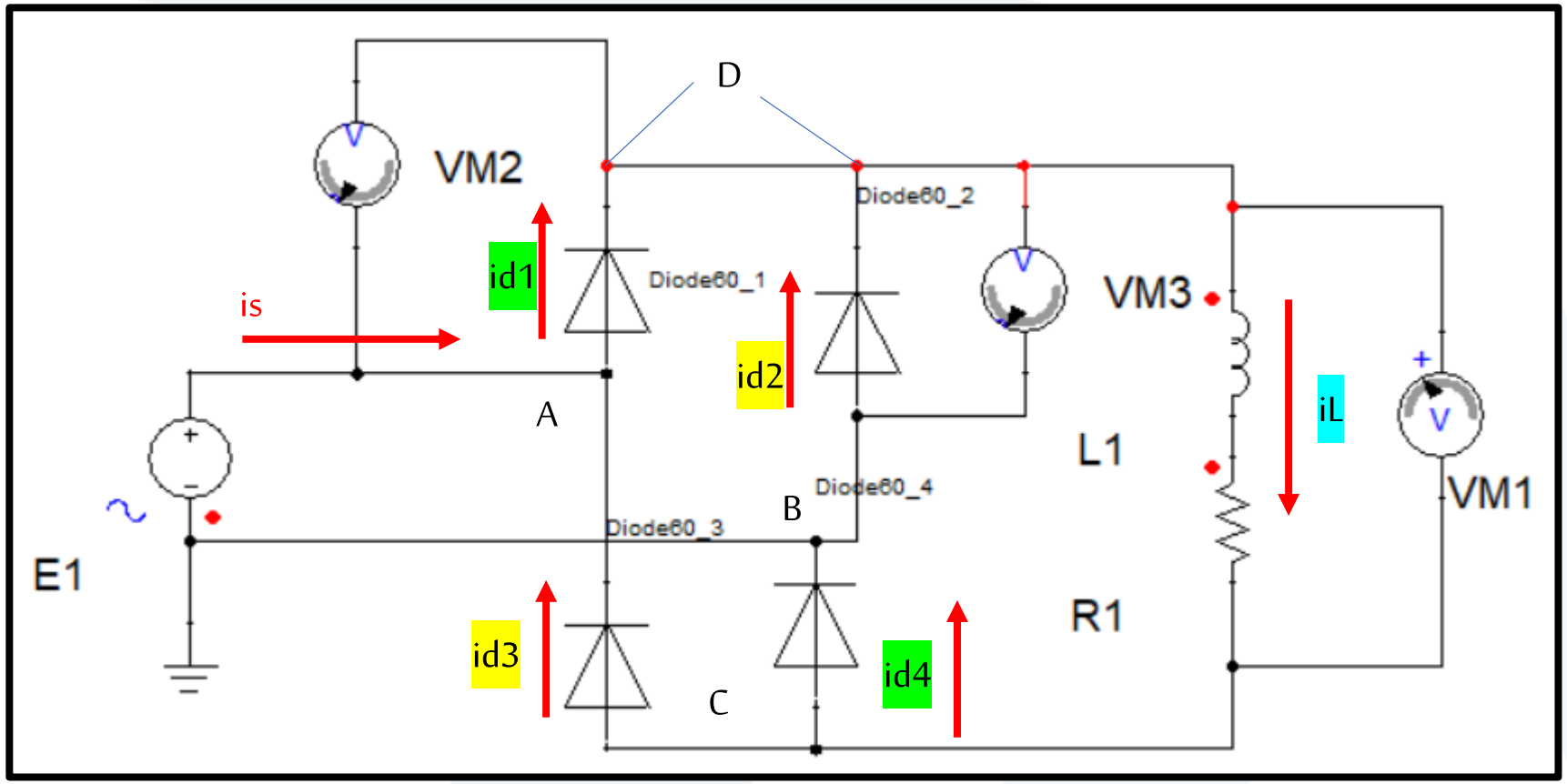
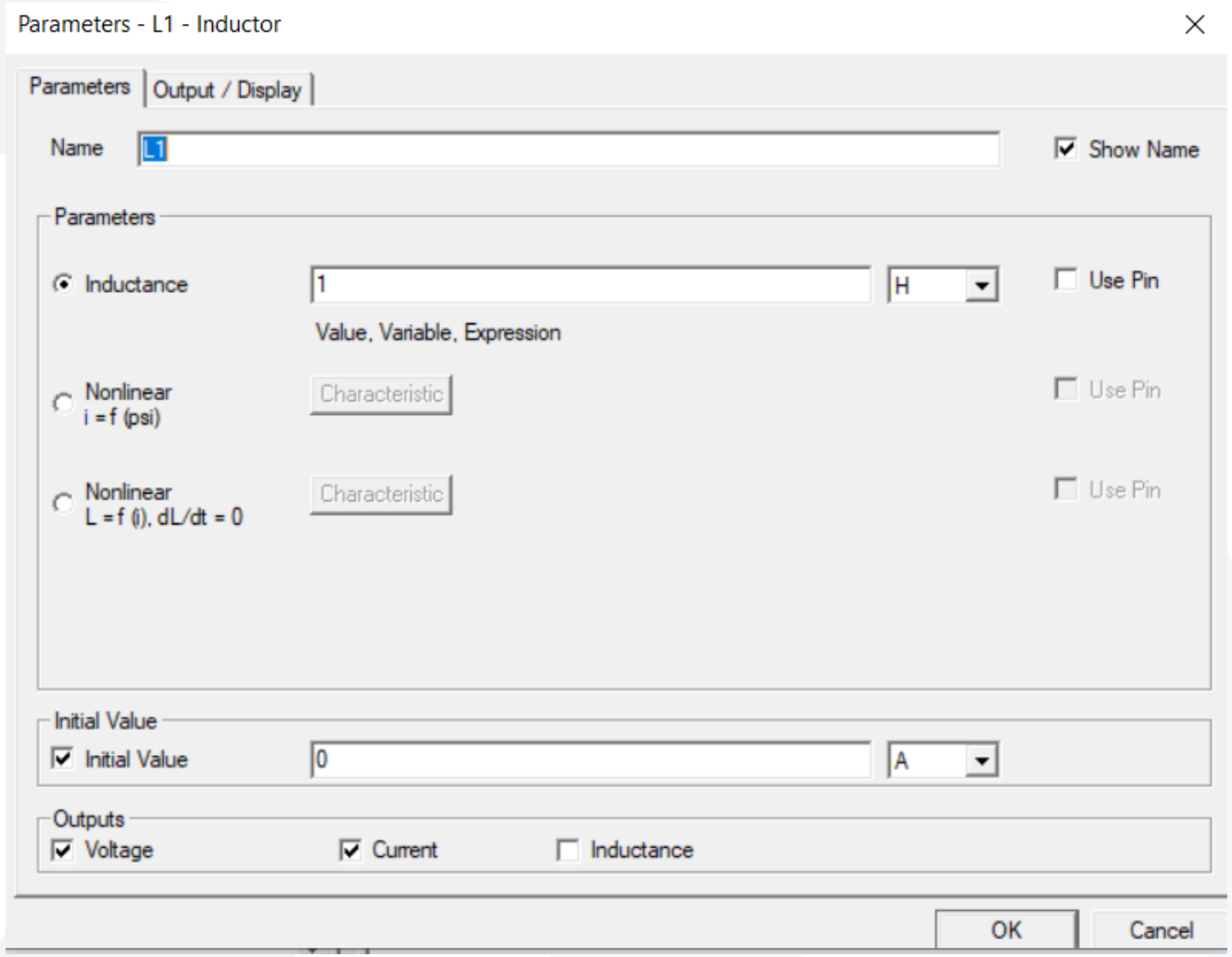
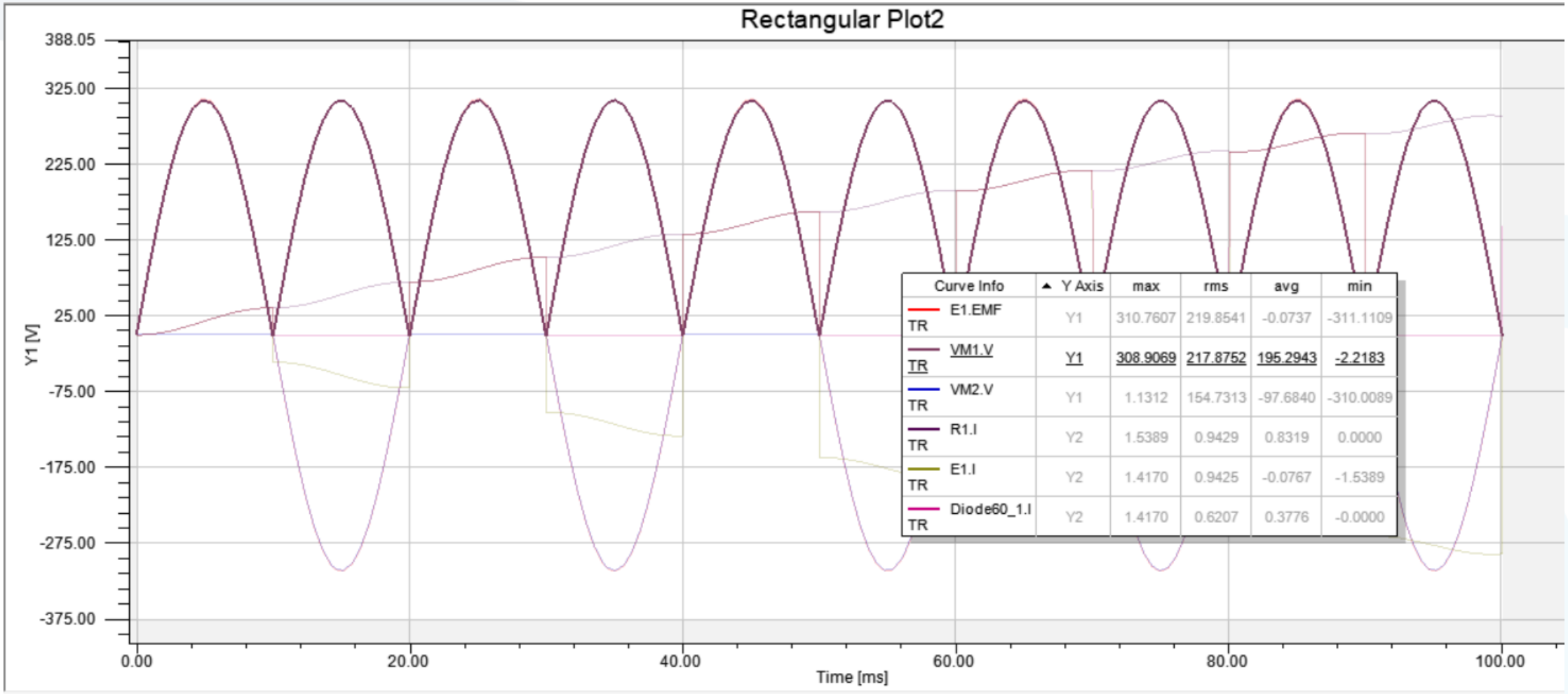
Diode60_1.I TR	Y2	6.1750	3.0781	1.9511	-0.0000
Diode60_3.I TR	Y2	6.1739	3.0781	1.9511	-0.0000

حمولة مختلطة أومية مع تحريضية

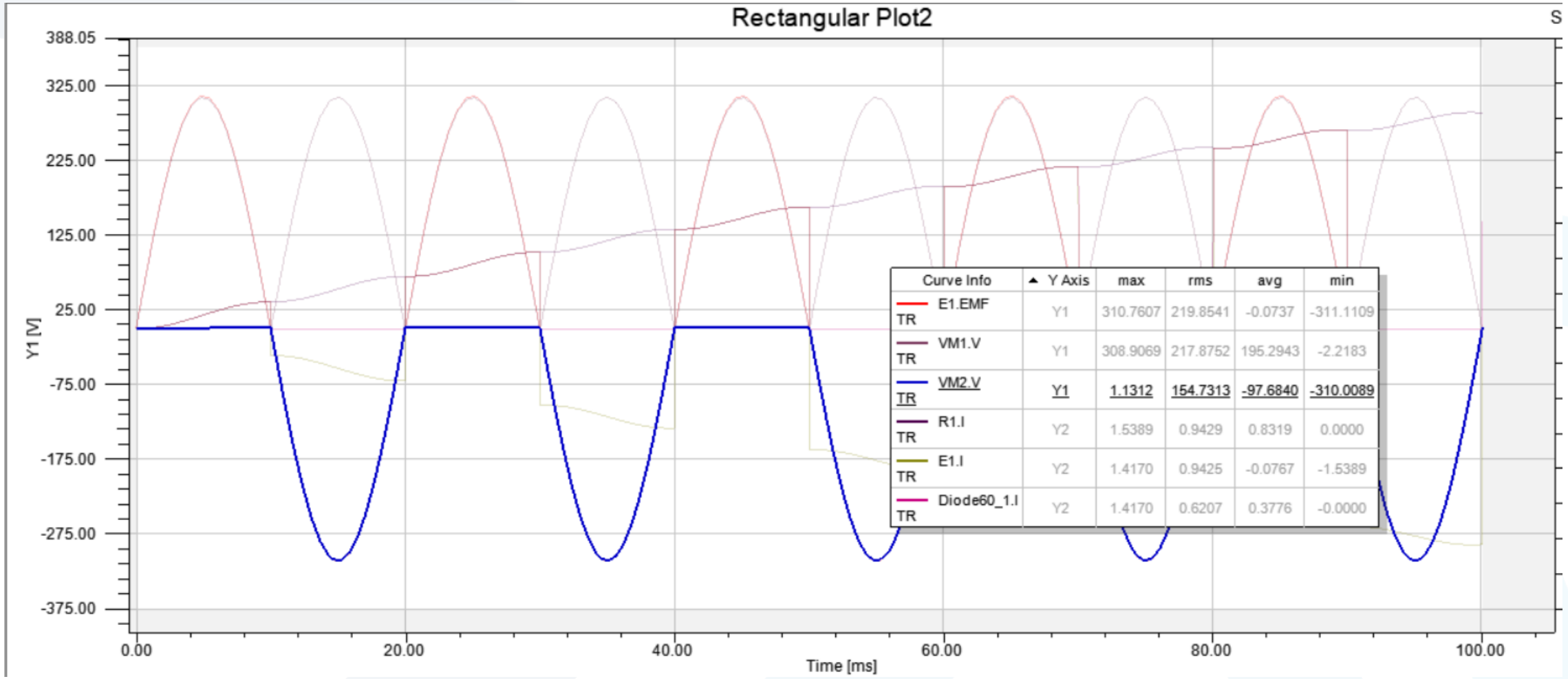



Parameters - L1 - Inductor
Parameters
Output / Display
Name
L1
Show Name
Parameters
Inductance
1
H
Use Pin
Value, Variable, Expression
Nonlinear
i = f (psi)
Characteristic
Use Pin
Nonlinear
L = f (i), dL/dt = 0
Characteristic
Use Pin
Initial Value
Initial Value
0
A
Outputs
Voltage
Current
Inductance
OK
Cancel

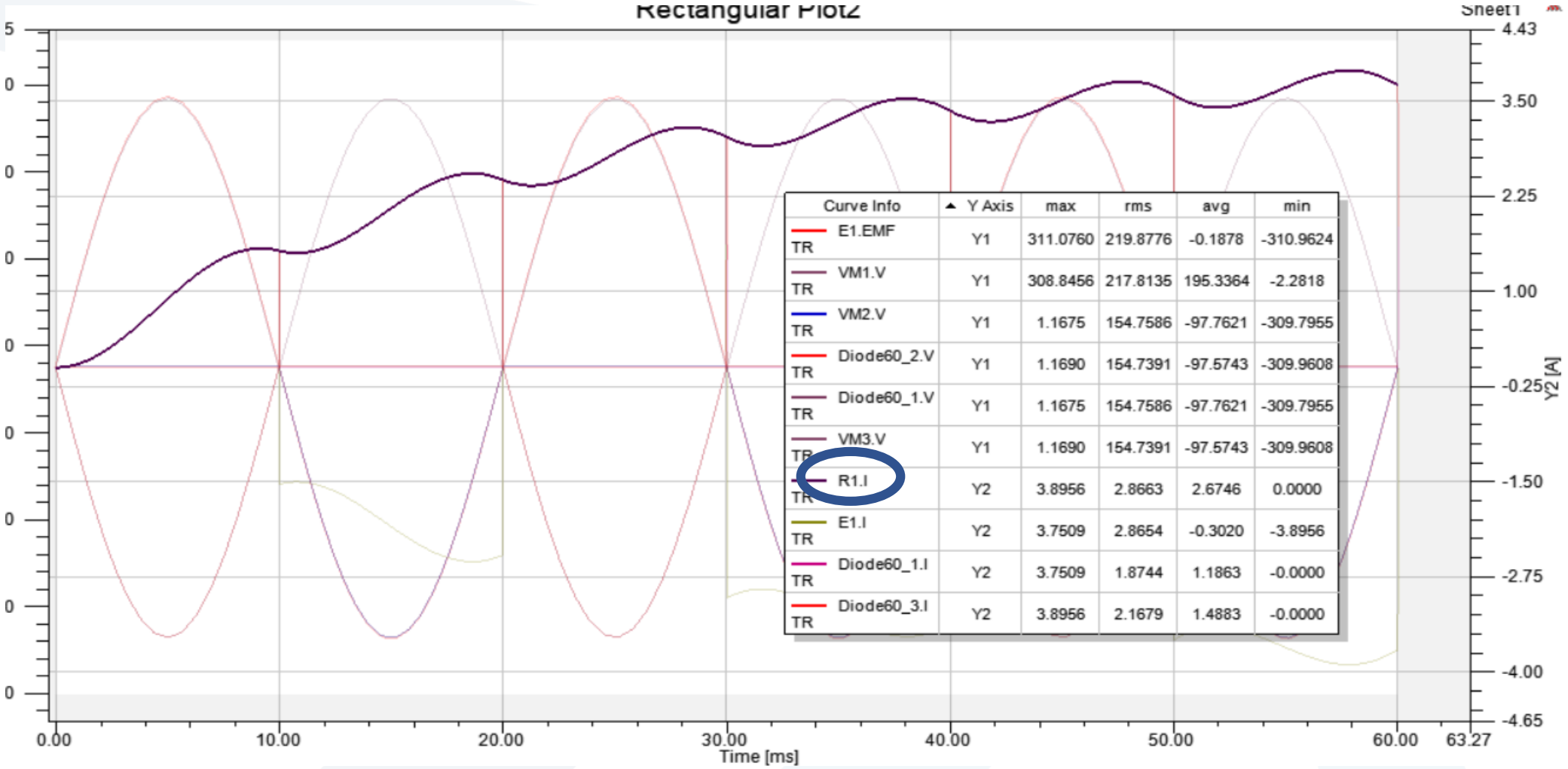
جهد الحمل

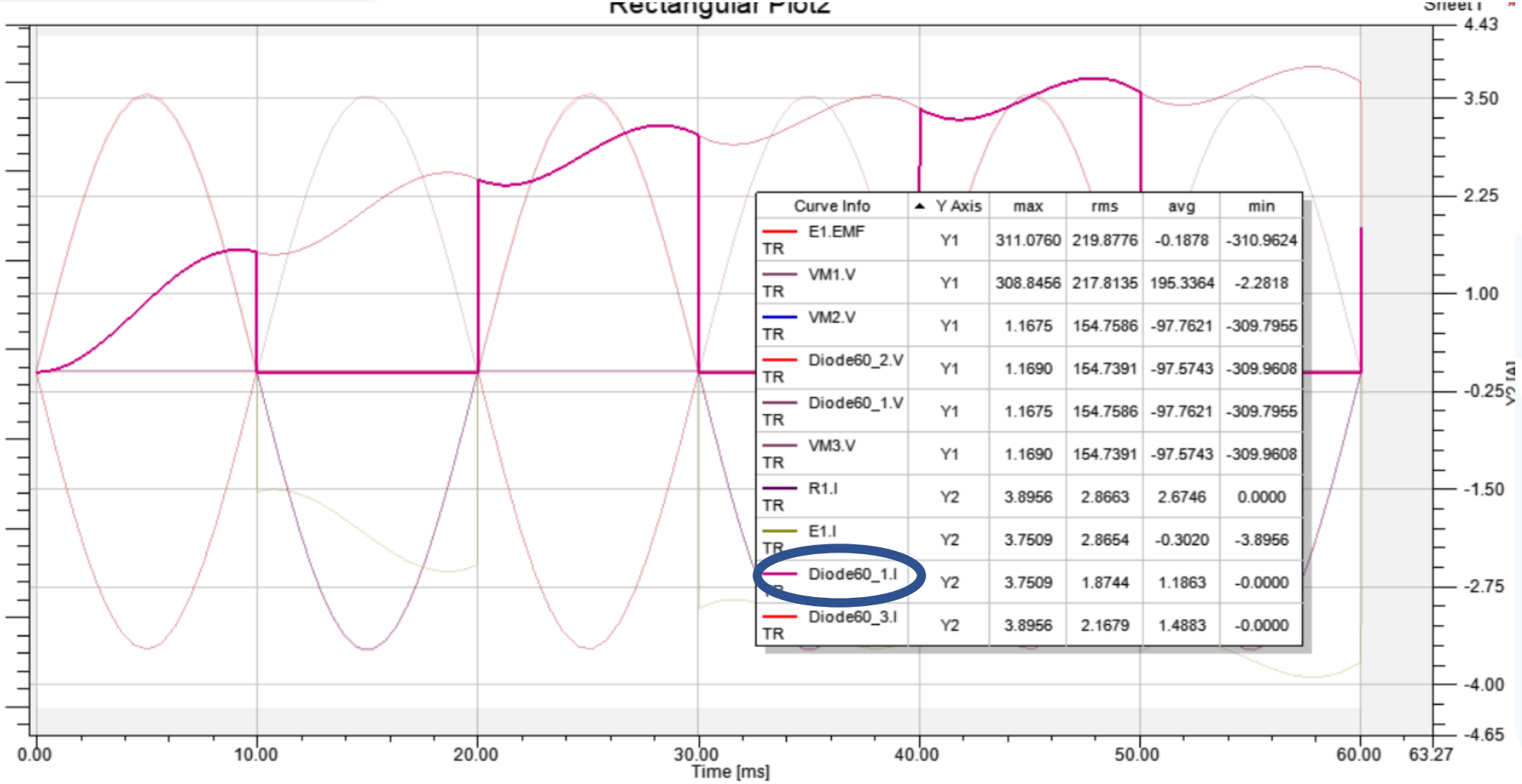

Rectangular Plot2
388.05
325.00
225.00
125.00
25.00
-75.00
-175.00
-275.00
-375.00
Y1 [V]
0.00
20.00
40.00
60.00
80.00
100.00
Time [ms]
Curve Info | Y Axis | max | rms | avg | min
E1.EMF TR | Y1 | 310.7607 | 219.8541 | -0.0737 | -311.1109
VM1.V TR | Y1 | 308.9069 | 217.8752 | 195.2943 | -2.2183
VM2.V TR | Y1 | 1.1312 | 154.7313 | -97.6840 | -310.0089
R1.I TR | Y2 | 1.5389 | 0.9429 | 0.8319 | 0.0000
E1.I TR | Y2 | 1.4170 | 0.9425 | -0.0767 | -1.5389
Diode60_1.I TR | Y2 | 1.4170 | 0.6207 | 0.3776 | -0.0000

جهد الديود الأول



تيار الحمل

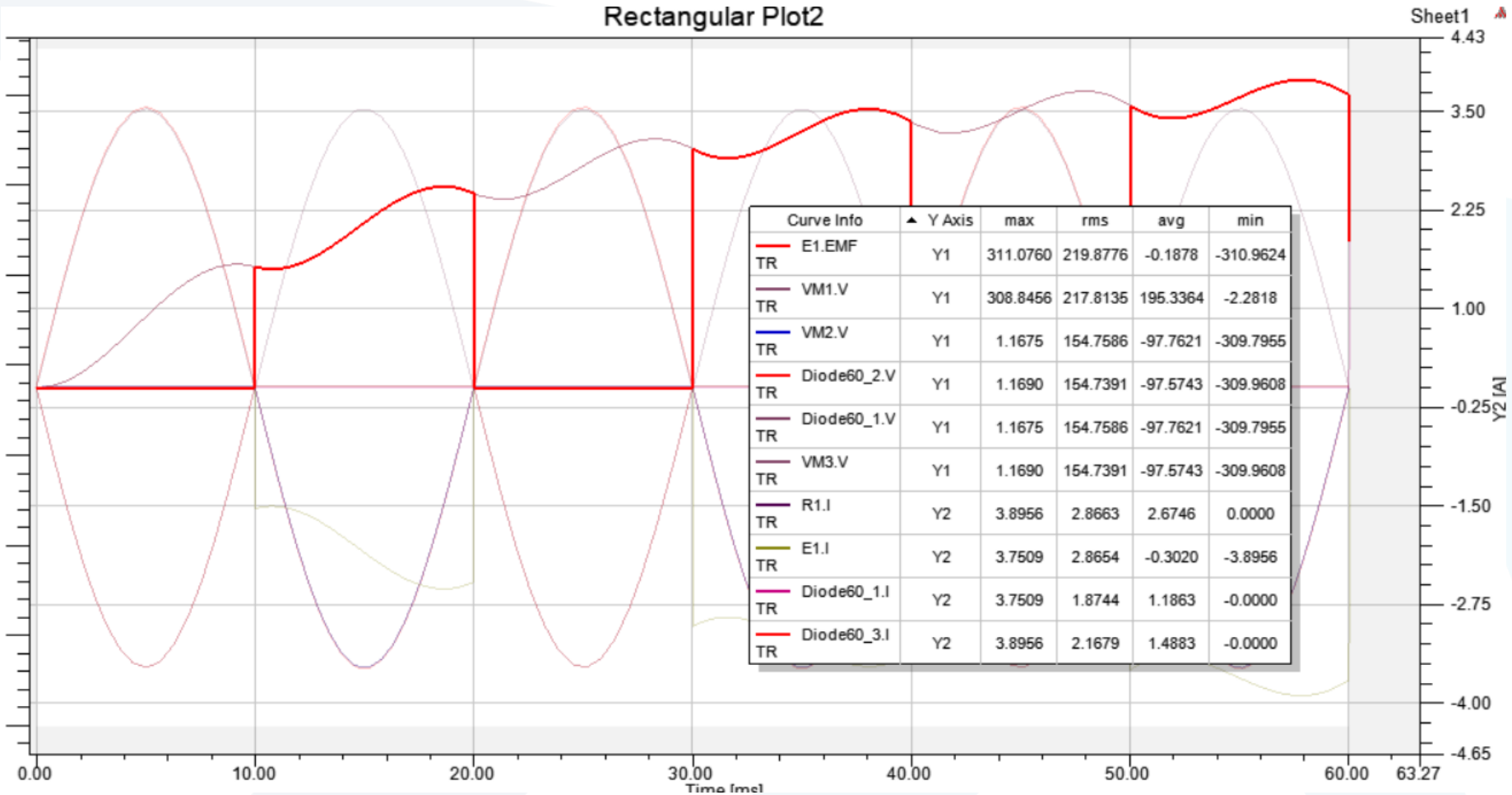

Rectangular Plot2
Sheet1
Curve Info | Y Axis | max | rms | avg | min
E1.EMF TR | Y1 | 311.0760 | 219.8776 | -0.1878 | -310.9624
VM1.V TR | Y1 | 308.8456 | 217.8135 | 195.3364 | -2.2818
VM2.V TR | Y1 | 1.1675 | 154.7586 | -97.7621 | -309.7955
Diode60_2.V TR | Y1 | 1.1690 | 154.7391 | -97.5743 | -309.9608
Diode60_1.V TR | Y1 | 1.1675 | 154.7586 | -97.7621 | -309.7955
VM3.V TR | Y1 | 1.1690 | 154.7391 | -97.5743 | -309.9608
R1.I TR | Y2 | 3.8956 | 2.8663 | 2.6746 | 0.0000
E1.I TR | Y2 | 3.7509 | 2.8654 | -0.3020 | -3.8956
Diode60_1.I TR | Y2 | 3.7509 | 1.8744 | 1.1863 | -0.0000
Diode60_3.I TR | Y2 | 3.8956 | 2.1679 | 1.4883 | -0.0000
Time [ms]
Y2 [A]
0.00
10.00
20.00
30.00
40.00
50.00
60.00
63.27
4.43
3.50
2.25
1.00
-0.25
-1.50
-2.75
-4.00
-4.65



Curve Info	Y Axis	max	rms	avg	min
E1.EMF TR	Y1	311.0760	219.8776	-0.1878	-310.9624
VM1.V TR	Y1	308.8456	217.8135	195.3364	-2.2818
VM2.V TR	Y1	1.1675	154.7586	-97.7621	-309.7955
Diode60_2.V TR	Y1	1.1690	154.7391	-97.5743	-309.9608
Diode60_1.V TR	Y1	1.1675	154.7586	-97.7621	-309.7955
VM3.V TR	Y1	1.1690	154.7391	-97.5743	-309.9608
R1.I TR	Y2	3.8956	2.8663	2.6746	0.0000
E1.I TR	Y2	3.7509	2.8654	-0.3020	-3.8956
Diode60_1.I	Y2	3.7509	1.8744	1.1863	-0.0000
Diode60_3.I TR	Y2	3.8956	2.1679	1.4883	-0.0000

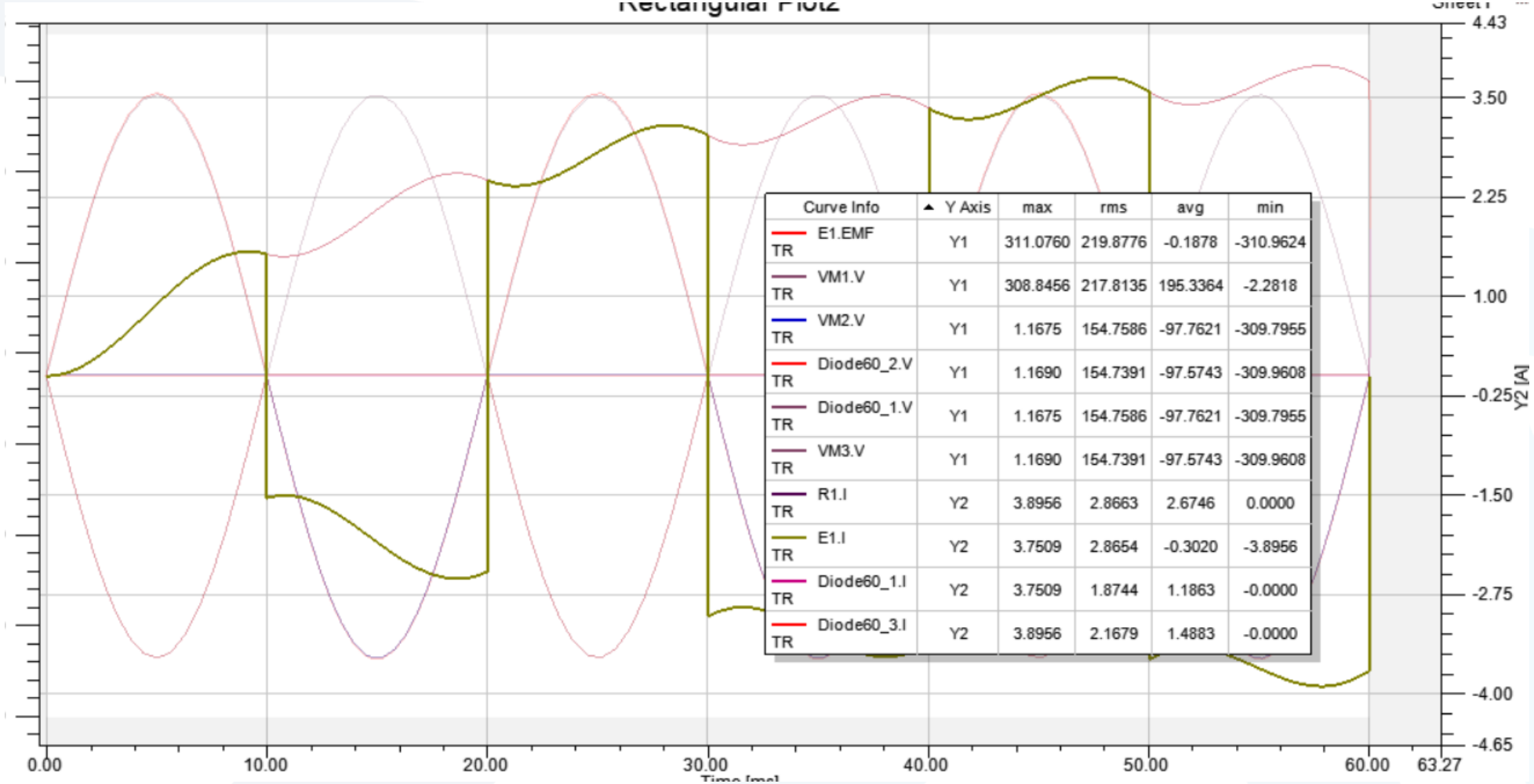
تيار الديود
الأول والرابع

تيار الديود الثالث والثاني



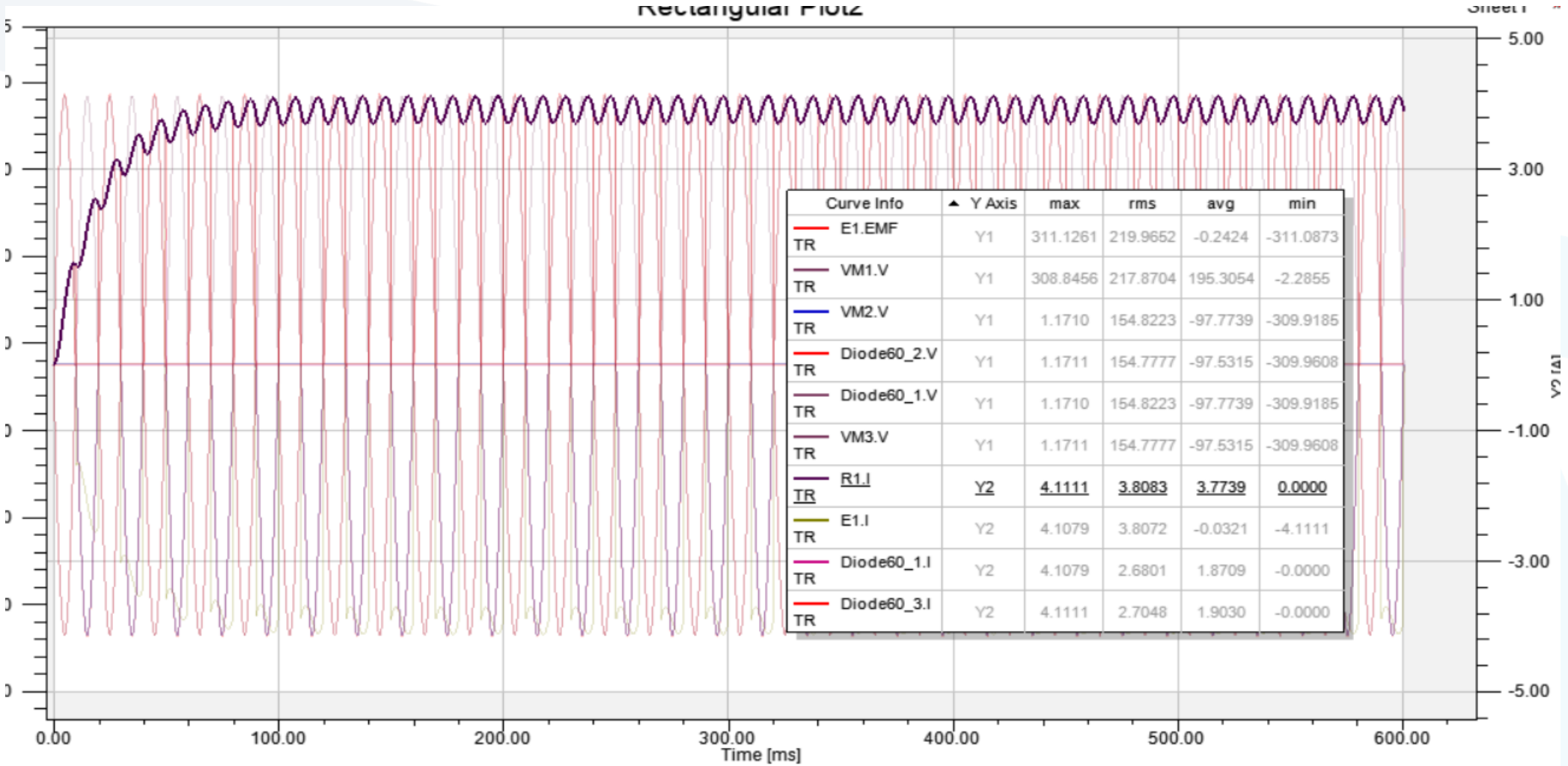
Curve Info	Y Axis	max	rms	avg	min
E1.EMF TR	Y1	311.0760	219.8776	-0.1878	-310.9624
VM1.V TR	Y1	308.8456	217.8135	195.3364	-2.2818
VM2.V TR	Y1	1.1675	154.7586	-97.7621	-309.7955
Diode60_2.V TR	Y1	1.1690	154.7391	-97.5743	-309.9608
Diode60_1.V TR	Y1	1.1675	154.7586	-97.7621	-309.7955
VM3.V TR	Y1	1.1690	154.7391	-97.5743	-309.9608
R1.I TR	Y2	3.8956	2.8663	2.6746	0.0000
E1.I TR	Y2	3.7509	2.8654	-0.3020	-3.8956
Diode60_1.I TR	Y2	3.7509	1.8744	1.1863	-0.0000
Diode60_3.I TR	Y2	3.8956	2.1679	1.4883	-0.0000

تيار المنبع



Curve Info	Y Axis	max	rms	avg	min
E1.EMF TR	Y1	311.0760	219.8776	-0.1878	-310.9624
VM1.V TR	Y1	308.8456	217.8135	195.3364	-2.2818
VM2.V TR	Y1	1.1675	154.7586	-97.7621	-309.7955
Diode60_2.V TR	Y1	1.1690	154.7391	-97.5743	-309.9608
Diode60_1.V TR	Y1	1.1675	154.7586	-97.7621	-309.7955
VM3.V TR	Y1	1.1690	154.7391	-97.5743	-309.9608
R1.I TR	Y2	3.8956	2.8663	2.6746	0.0000
E1.I TR	Y2	3.7509	2.8654	-0.3020	-3.8956
Diode60_1.I TR	Y2	3.7509	1.8744	1.1863	-0.0000
Diode60_3.I TR	Y2	3.8956	2.1679	1.4883	-0.0000

Curve Info	Y Axis	max	rms	avg	min
E1.EMF TR	Y1	311.0760	219.8776	-0.1878	-310.9624
VM1.V TR	Y1	308.8456	217.8135	195.3364	-2.2818
VM2.V TR	Y1	1.1675	154.7586	-97.7621	-309.7955
Diode60_2.V TR	Y1	1.1690	154.7391	-97.5743	-309.9608
Diode60_1.V TR	Y1	1.1675	154.7586	-97.7621	-309.7955
VM3.V TR	Y1	1.1690	154.7391	-97.5743	-309.9608
R1.I TR	Y2	3.8956	2.8663	2.6746	0.0000
E1.I TR	Y2	3.7509	2.8654	-0.3020	-3.8956
Diode60_1.I TR	Y2	3.7509	1.8744	1.1863	-0.0000
Diode60_3.I TR	Y2	3.8956	2.1679	1.4883	-0.0000


Rectangular Plot2
5.00
3.00
1.00
-1.00
-3.00
-5.00
0.00
100.00
200.00
300.00
400.00
500.00
600.00
Time [ms]
Curve Info | Y Axis | max | rms | avg | min
E1.EMF TR | Y1 | 311.1261 | 219.9652 | -0.2424 | -311.0873
VM1.V TR | Y1 | 308.8456 | 217.8704 | 195.3054 | -2.2855
VM2.V TR | Y1 | 1.1710 | 154.8223 | -97.7739 | -309.9185
Diode60_2.V TR | Y1 | 1.1711 | 154.7777 | -97.5315 | -309.9608
Diode60_1.V TR | Y1 | 1.1710 | 154.8223 | -97.7739 | -309.9185
VM3.V TR | Y1 | 1.1711 | 154.7777 | -97.5315 | -309.9608
R1.I TR | Y2 | 4.1111 | 3.8083 | 3.7739 | 0.0000
E1.I TR | Y2 | 4.1079 | 3.8072 | -0.0321 | -4.1111
Diode60_1.I TR | Y2 | 4.1079 | 2.6801 | 1.8709 | -0.0000
Diode60_3.I TR | Y2 | 4.1111 | 2.7048 | 1.9030 | -0.0000

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