

الالكترونيات الطاقة

Lecture No. 6

دارة تقويم موجة كاملة ثلاثية الطور جسرية

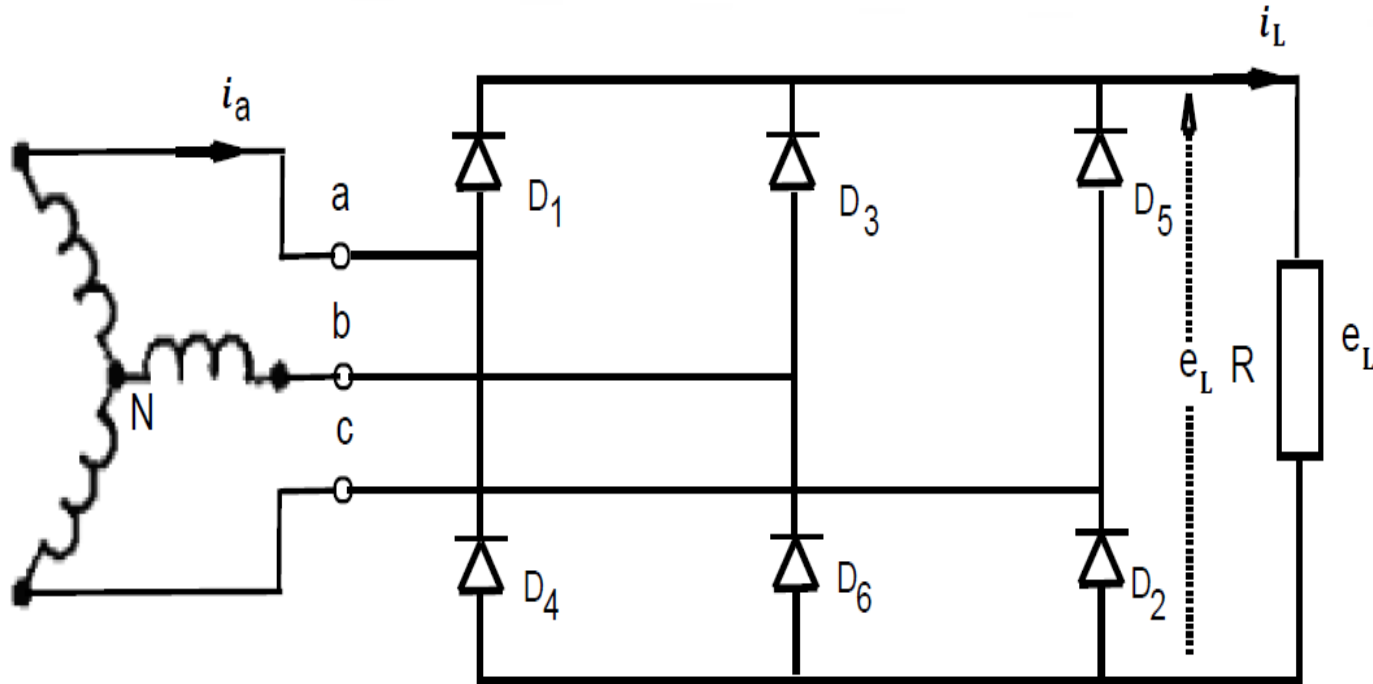
ميكاترونيكس - سنة رابعة - فصل ثاني

Dr. Eng. Essa Alghannam

Ph.D. Degree in Mechatronics Engineering

2023

دارة تقويم موجة كاملة ثلاثية الطور جسرية



جهود الأطوار:

$$e_1 = e_{an} = u_2 = U_{2m} \sin(\theta) = \sqrt{2}U_{2rms} \sin(\theta)$$

$$e_2 = e_{bn} = U_{2m} \sin(\theta - 120)$$

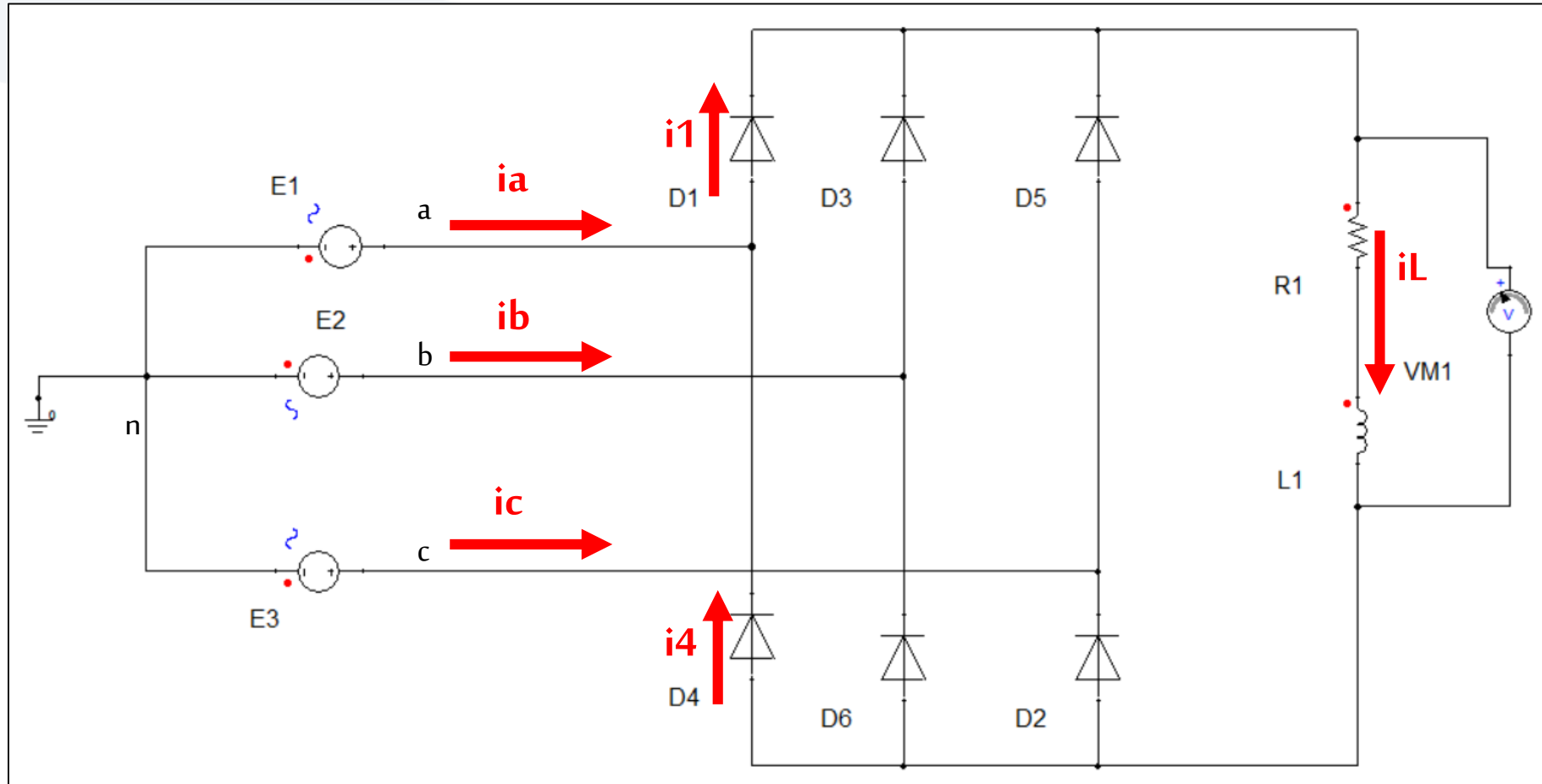
$$e_3 = e_{cn} = U_{2m} \sin(\theta + 120)$$

جهود الخطوط:

$$e_{ab} = \sqrt{3}U_{2m} \sin\left(\theta + \frac{\pi}{6}\right)$$

$$e_{bc} = \sqrt{3}U_{2m} \sin\left(\theta - \frac{\pi}{2}\right)$$

$$e_{ca} = \sqrt{3}U_{2m} \sin\left(\theta - \frac{7\pi}{6}\right) = \sqrt{3}U_{2m} \sin\left(\theta + \frac{5\pi}{6}\right)$$



Parameters - E1 - Voltage Source

Parameters | AC - Parameters | Output / Display

Name Show Name

Parameters

EMF Value Use Pin
Value, Variable, Expression AC use

Time Controlled

Spice compatible

RMS Value

Amplitude Phase

Frequency Offset

Period Rise Time

Periodical Fall Time

Delay Pulse Width

Outputs

Voltage Current EMF Value

OK Cancel

Parameters - E2 - Voltage Source

Parameters | AC - Parameters | Output / Display

Name Show Name

Parameters

EMF Value Use Pin
Value, Variable, Expression AC use

Time Controlled

Spice compatible

RMS Value

Amplitude Phase

Frequency Offset

Period Rise Time

Periodical Fall Time

Delay Pulse Width

Outputs

Voltage Current EMF Value

OK Cancel

Parameters - E3 - Voltage Source

Parameters | AC - Parameters | Output / Display

Name Show Name

Parameters

EMF Value Use Pin
Value, Variable, Expression AC use

Time Controlled

Spice compatible

RMS Value

Amplitude Phase

Frequency Offset

Period Rise Time

Periodical Fall Time

Delay Pulse Width

Outputs

Voltage Current EMF Value

OK Cancel

جهود الأطوار:

$$e_1 = e_{an} = u_2 = U_{2m} \sin(\theta) = \sqrt{2}U_{2rms} \sin(\theta)$$

$$e_2 = e_{bn} = U_{2m} \sin(\theta - 120)$$

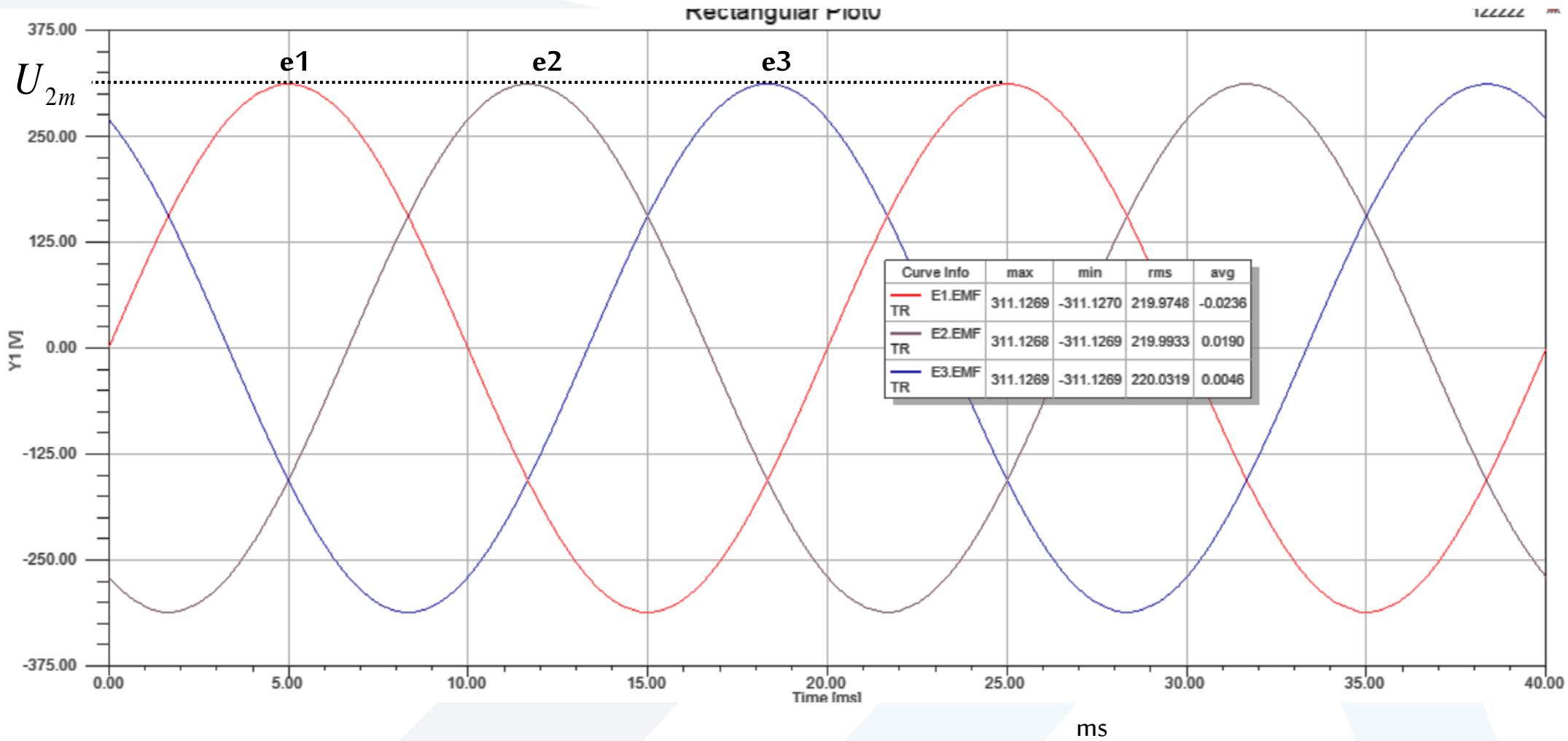
$$e_3 = e_{cn} = U_{2m} \sin(\theta + 120)$$

$$e_{ab} = \sqrt{3}U_{2m} \sin\left(\theta + \frac{\pi}{6}\right)$$

$$e_{bc} = \sqrt{3}U_{2m} \sin\left(\theta - \frac{\pi}{2}\right)$$

$$e_{ca} = \sqrt{3}U_{2m} \sin\left(\theta - \frac{7\pi}{6}\right) = \sqrt{3}U_{2m} \sin\left(\theta + \frac{5\pi}{6}\right)$$

جهود الخطوط:



Parameters - D1 - Diode ×

Parameters | Output / Display

Name Show Name

Parameters

Type

Forward Voltage	Bulk Resistance	Reverse Resistance
<input type="text" value="0.8"/> <input type="text" value="V"/>	<input type="text" value="0.001"/> <input type="text" value="ohm"/>	<input type="text" value="100000"/> <input type="text" value="ohm"/>

Element Name Use Pin

Outputs

Voltage Current

Parameters - R1 - Resistor

Parameters | Output / Display

Name Show Name

Parameters

Resistance ohm Use Pin
Value, Variable, Expression

Nonlinear Use Pin
 $i = f(v)$

Outputs

Voltage Current Resistance

OK Cancel

Parameters - L1 - Inductor ×

Parameters | Output / Display

Name Show Name

Parameters

Inductance H Use Pin
Value, Variable, Expression

Nonlinear
 $i = f(\psi)$ Use Pin

Nonlinear
 $L = f(i), dL/dt = 0$ Use Pin

Initial Value

Initial Value A

Outputs

Voltage Current Inductance

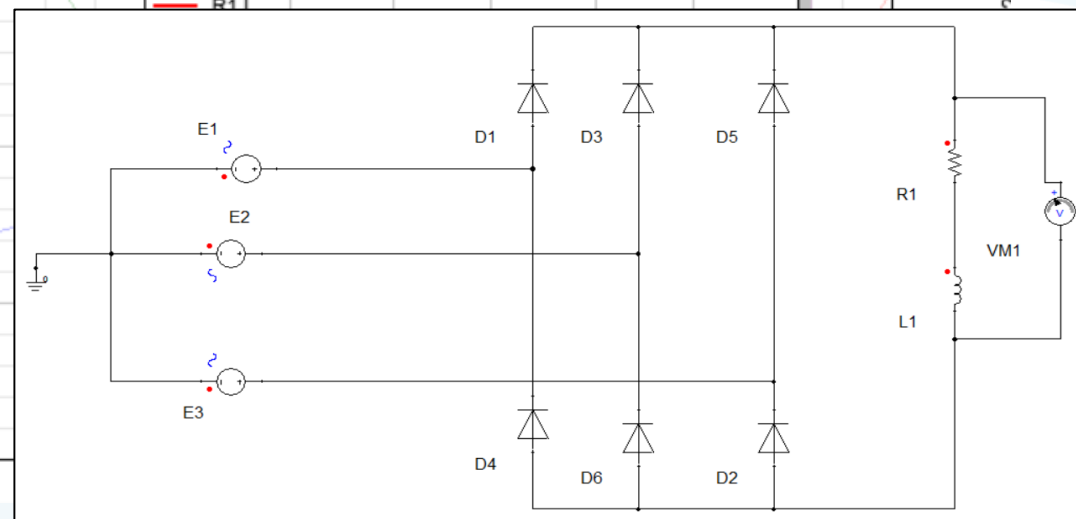
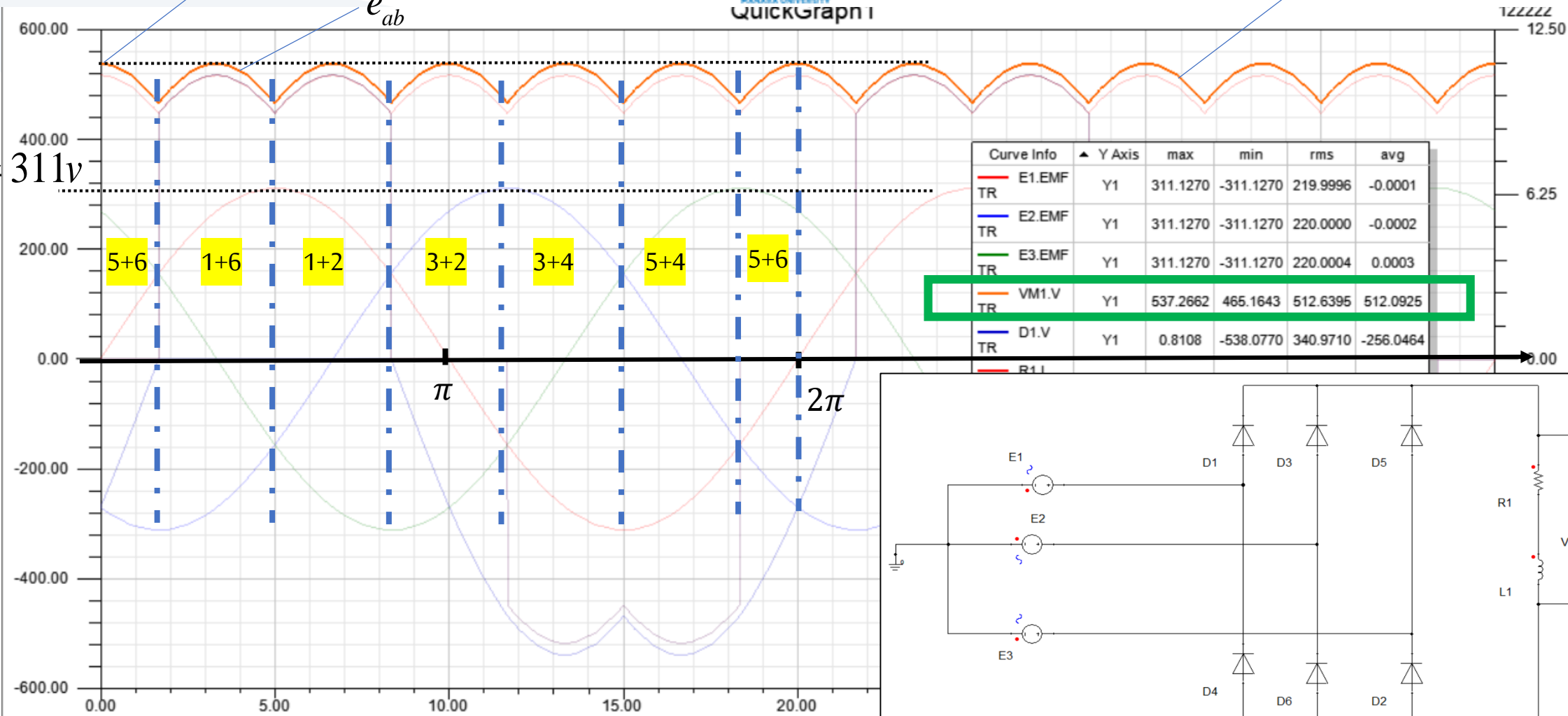
تصفير قيمة المحارضة
حمل أومي صرف

جهد الحمل $u_L(\theta)$

$$\sqrt{3}U_{2m} \approx 538v$$

e_{ab}

$$U_{2m} \approx 311v$$



بارامترات جهد الحمل

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

القيمة المتوسطة لجهد الحمل

قيمة جهد الحمل المقوم المتوسطة

$$\begin{aligned}
 U_{L_{av}} &= \frac{6}{2\pi} \left[\int_{\frac{\pi}{6}}^{\frac{\pi}{2}} \sqrt{3}U_{2m} \sin\left(\theta + \frac{\pi}{6}\right).d\theta \right] = \frac{-6\sqrt{3}U_{2m}}{2\pi} \left[\cos\left(\theta + \frac{\pi}{6}\right) \right]_{\frac{\pi}{6}}^{\frac{\pi}{2}} \\
 &= \frac{-6\sqrt{3}U_{2m}}{2\pi} [\cos 120 - \cos 60] \\
 &= \frac{-6\sqrt{3}U_{2m}}{2\pi} \left[-\frac{1}{2} - \frac{1}{2} \right] \\
 &= \frac{6\sqrt{3}U_{2m}}{2\pi} = \frac{3\sqrt{3}U_{2m}}{\pi} = U_{L_{av0}} = 1.654U_{2m} = 1.654\sqrt{2}U_{2rms} = 2.34U_{2rms} = 2.34 * 220 \approx 514.6v
 \end{aligned}$$

قيمة جهد الدخل العظمى

قيمة جهد الدخل الفعالة

العلاقة السابقة تربط قيمة جهد الدخل الفعالة وقيمة جهد الحمل المتوسطة

$$\frac{6}{2\pi} \sqrt{3}U_{2m} = \frac{3}{\pi} U_{line_{max}} = 0.955U_{line_{max}}$$

بارامترات جهد الحمل

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

القيمة الفعالة لجهد الحمل

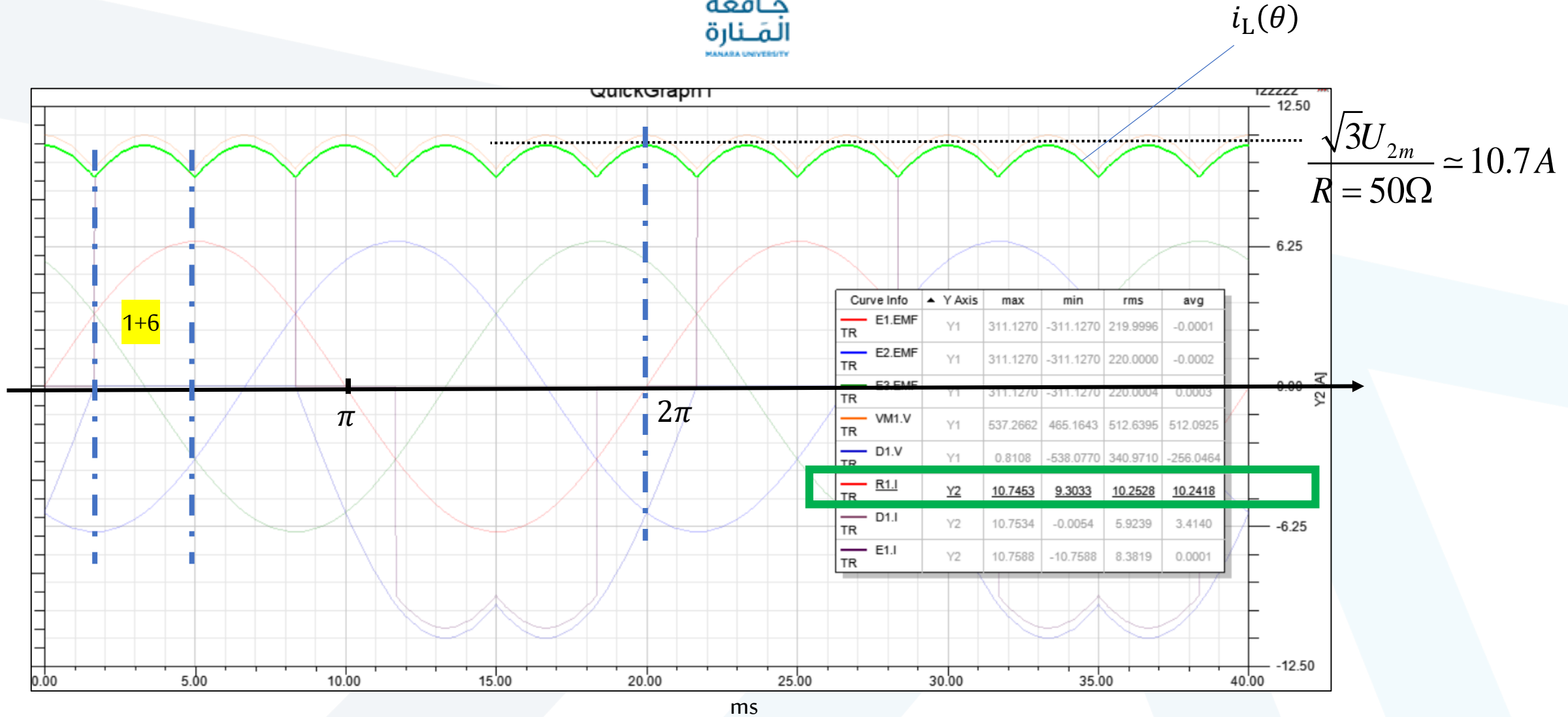
قيمة جهد الدخل الطور العظمى

قيمة جهد الحمل الفعالة

$$U_{L_{rms}} = \sqrt{\frac{6}{2\pi} \int_{\frac{\pi}{6}}^{\frac{\pi}{2}} 3U_{2m}^2 \sin^2\left(\theta + \frac{\pi}{6}\right) d\theta} = \sqrt{\frac{18U_{2m}^2}{4\pi} \int_{\frac{\pi}{6}}^{\frac{\pi}{2}} \left(1 - \cos 2\left(\theta + \frac{\pi}{6}\right)\right) d\theta}$$

$$= \sqrt{\frac{18U_{2m}^2}{4\pi} \left[\theta \right]_{\frac{\pi}{6}}^{\frac{\pi}{2}} - \frac{1}{2} \left[\sin 2\left(\theta + \frac{\pi}{6}\right) \right]_{\frac{\pi}{6}}^{\frac{\pi}{2}}} = \sqrt{\frac{18U_{2m}^2}{4\pi} \left[\frac{\pi}{3} - \frac{1}{2} \left[\sin 2\left(\frac{\pi}{2} + \frac{\pi}{6}\right) - \sin 2\left(\frac{\pi}{6} + \frac{\pi}{6}\right) \right] \right]}$$

$$= \sqrt{\frac{18U_{2m}^2}{4\pi} \left[\frac{\pi}{3} - \frac{1}{2} [\sin 240 - \sin 120] \right]} = \sqrt{\frac{18U_{2m}^2}{4\pi} \left[\frac{\pi}{3} - \frac{1}{2} \left[\frac{-\sqrt{3}}{2} - \frac{\sqrt{3}}{2} \right] \right]} = \sqrt{\frac{18U_{2m}^2}{4\pi} \left[\frac{\pi}{3} + \frac{\sqrt{3}}{2} \right]} = \sqrt{\frac{18}{4\pi} \left[\frac{\pi}{3} + \frac{\sqrt{3}}{2} \right]} U_{2m} = 1.655U_{2m}$$



بارامترات تيار الحمل

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

القيمة المتوسطة لتيار الحمل

قيمة جهد الدخل العظمى

قيمة جهد الدخل الفعالة

$$I_{L_{av}} = \frac{6}{2\pi} \left[\int_{\frac{\pi}{6}}^{\frac{\pi}{2}} \frac{\sqrt{3}U_{2m}}{R} \sin\left(\theta + \frac{\pi}{6}\right) \cdot d\theta \right] = \frac{6\sqrt{3}U_{2m}}{2\pi R} = 1.654 \frac{U_{2m}}{R} = 1.654\sqrt{2} \frac{U_{2rms}}{R} = 2.34 \frac{U_{2rms}}{R} = 2.34 \frac{220}{50} \approx 10.296A$$

قيمة تيار الحمل المقوم المتوسطة

بارامترات تيار الحمل

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

القيمة الفعالة لتيار الحمل

قيمة تيار الحمل الفعالة

$$U_{L_{rms}} = \sqrt{\frac{6}{2\pi} \int_{\frac{\pi}{6}}^{\frac{\pi}{2}} 3U_{2m}^2 \sin^2 \left(\theta + \frac{\pi}{6} \right) .d\theta} = 1.655U_{2m}$$

قيمة جهد الدخل الفعالة

قيمة جهد الدخل العظمى

$$I_{L_{rms}} = \sqrt{\frac{6}{2\pi} \int_{\frac{\pi}{6}}^{\frac{\pi}{2}} \frac{3U_{2m}^2}{R^2} \sin^2 \left(\theta + \frac{\pi}{6} \right) .d\theta} = 1.655 \frac{U_{2m}}{R} = 1.655\sqrt{2} \frac{U_{2rms}}{R} = 1.655\sqrt{2} \frac{220}{50} = 10.298A$$

Form factor

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

F.F = RMS value / DC value

$$\frac{I_{L_{rms}}}{I_{L_{av}}} = \frac{1.655 \frac{U_{2m}}{R}}{1.654 \frac{U_{2m}}{R}} \approx 1$$

بنسب قيمتي التيار الفعّالة والمتوسطة إلى بعضها تنتج العلاقة التالية:

Ripples factor

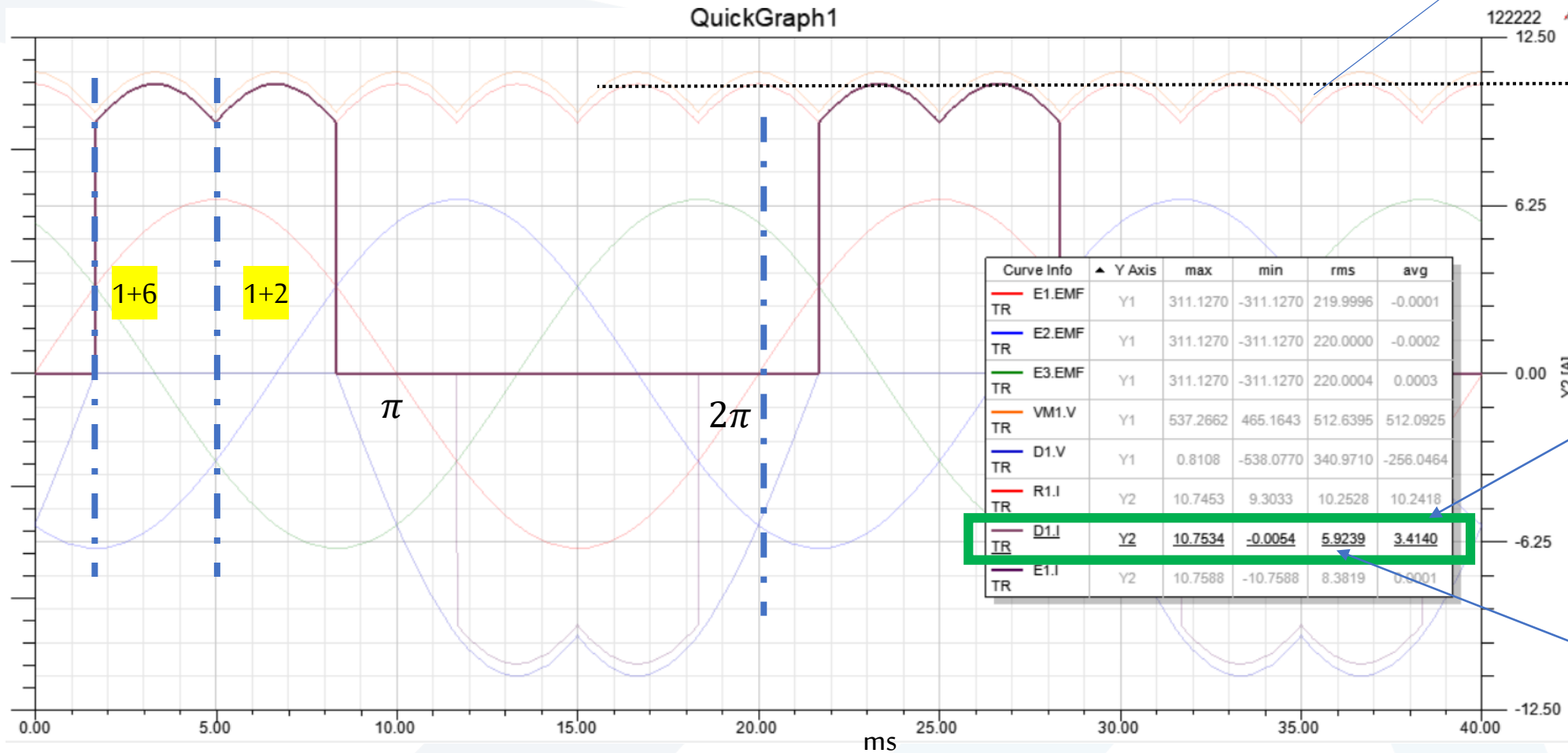
- Ripples factor = rms value of AC component of the output voltage / DC component of the output voltage
- The ripple factor is also simply defined as the ratio of ripple voltage to the DC voltage
- Ripple factor = Ratio of ripple voltage / DC voltage.
- The ripple factor should be kept as minimum as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

$$\gamma = \sqrt{\left(\frac{U_{L_{rms}}}{U_{L_{av}}}\right)^2 - 1} = \sqrt{\left(\frac{1.655U_{2m}}{1.654U_{2m}}\right)^2 - 1} \approx 0.03$$

- The unwanted ripple present in the output along with the DC voltage is 3% of the DC magnitude.

$i_{d1}(\theta)$

تيار الديود الأول بغياب المحارضة



$$\frac{\sqrt{3}U_{2m}}{R = 50\Omega} \approx 10.7A$$

تيار الديود قيمة
متوسطة

تيار الديود
قيمة فعالة

القيمة المتوسطة لتيار الديود

$$I_{D_{av}} = \frac{2}{2\pi} \left[\int_{\frac{\pi}{6}}^{\frac{\pi}{2}} \frac{\sqrt{3}U_{2m}}{R} \sin\left(\theta + \frac{\pi}{6}\right) .d\theta \right] = \frac{I_{L_{av}}}{3} = \frac{1.654 \frac{U_{2m}}{R}}{3} = 0.551 \frac{U_{2m}}{R} = 3.43A$$

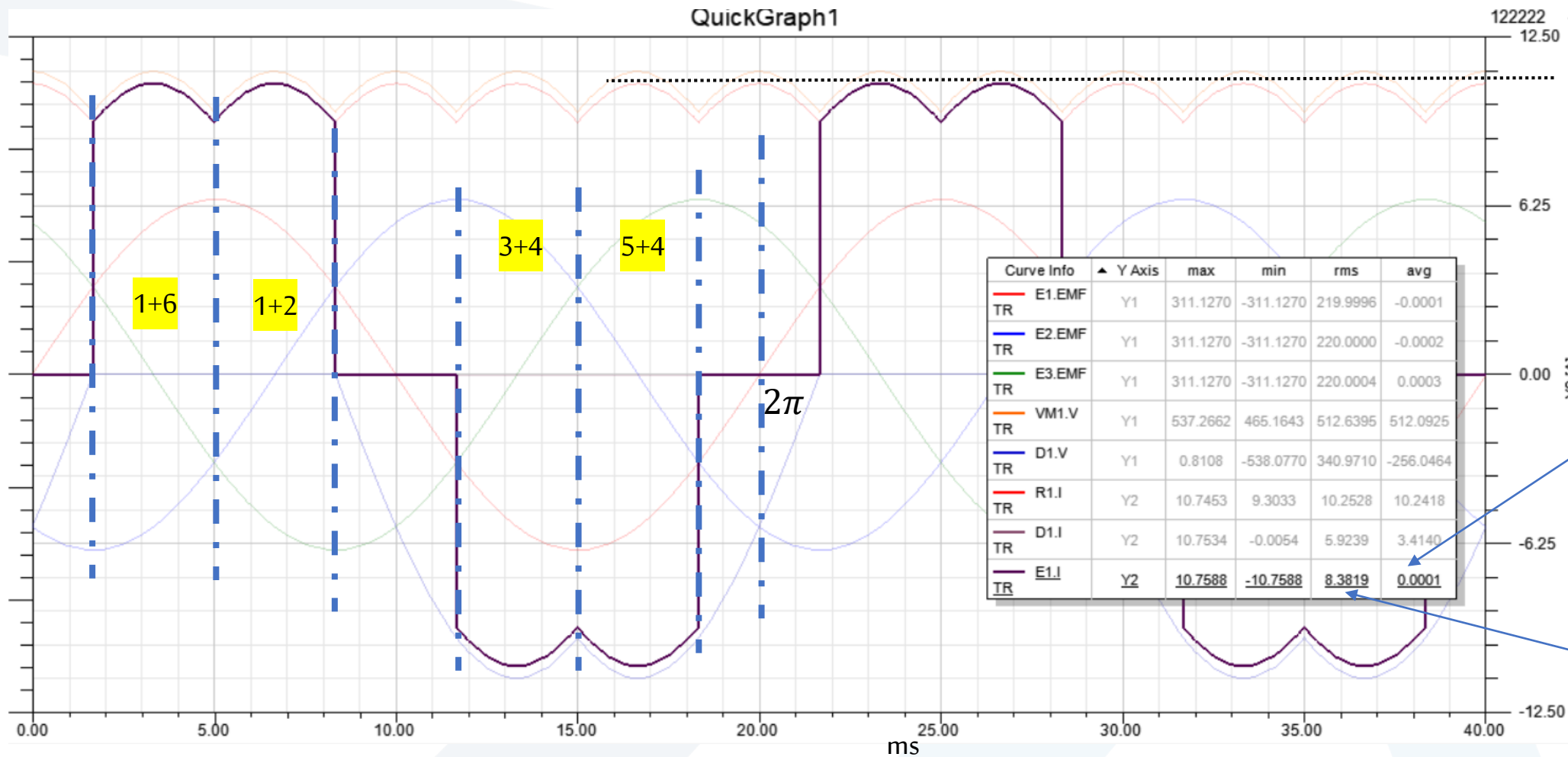
$$I_{D_{rms}} = \sqrt{\frac{2}{2\pi} \int_{\frac{\pi}{6}}^{\frac{\pi}{2}} \frac{3U_{2m}^2}{R^2} \sin^2\left(\theta + \frac{\pi}{6}\right) .d\theta} = \frac{I_{L_{rms}}}{\sqrt{3}} = \frac{1.655 \frac{U_{2m}}{R}}{\sqrt{3}} = 0.955 \frac{U_{2m}}{R} \approx 5.94A$$

القيمة الفعالة لتيار الديود



$i_a(\theta)$

تيار الطور الأول لمنبع التغذية بغياب المحارضة



$$\frac{\sqrt{3}U_{2m}}{R = 50\Omega} \approx 10.7A$$

تيار المنبع قيمة
متوسطة

تيار المنبع
قيمة فعالة

القيمة المتوسطة لتيار طور المنبع

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

$$I_{S_{rms}} = \sqrt{\frac{4}{2\pi} \int_{\frac{\pi}{6}}^{\frac{\pi}{2}} \frac{3U_{2m}^2}{R^2} \sin^2\left(\theta + \frac{\pi}{6}\right) d\theta} = \frac{\sqrt{2}I_{L_{rms}}}{\sqrt{3}} = \frac{\sqrt{2}}{\sqrt{3}} 1.655 \frac{U_{2m}}{R} = 1.351 \frac{U_{2m}}{R} \approx 8.4A$$

القيمة الفعالة لتيار المنبع

Rectifier efficiency

- Rectifier efficiency is defined as the ratio of output DC power to the input AC power.

$$P_{out} (DC) = I_{L_{av}}^2 R = 10.296^2 * 50 [W]$$

$$P_{in} (AC) = 3 I_{S_{rms}} U_{S_{rms}} = 3 * 8.4 * 220 [W]$$

$$\eta = \frac{P_{out} (DC)}{P_{in} (AC)} = \frac{I_{L_{av}}^2 R}{3 I_{S_{rms}} U_{S_{rms}}} = \frac{10.296^2 * 50 [W]}{3 * 8.4 * 220 [W]} \simeq 95.6\%$$

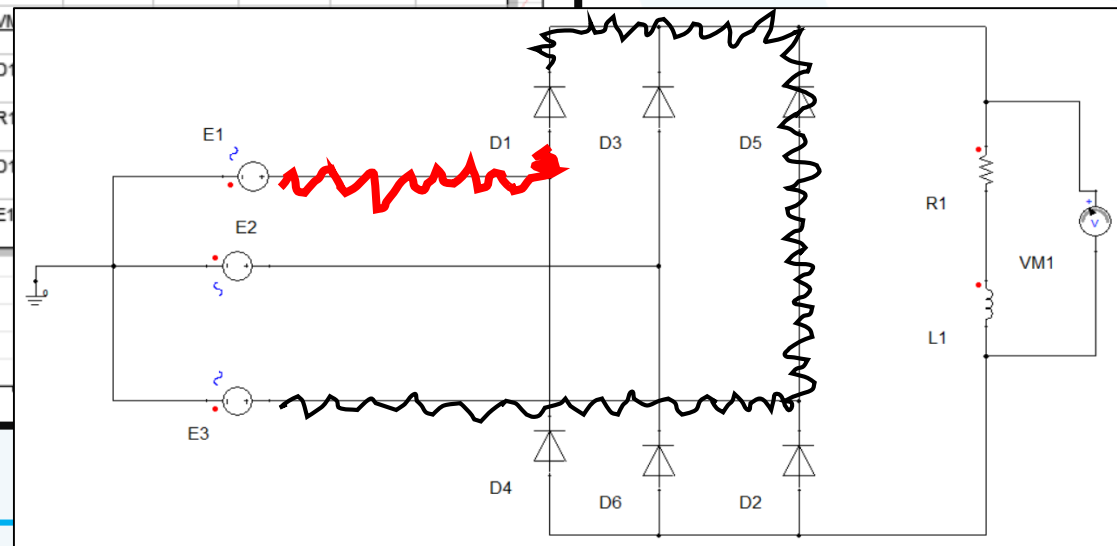
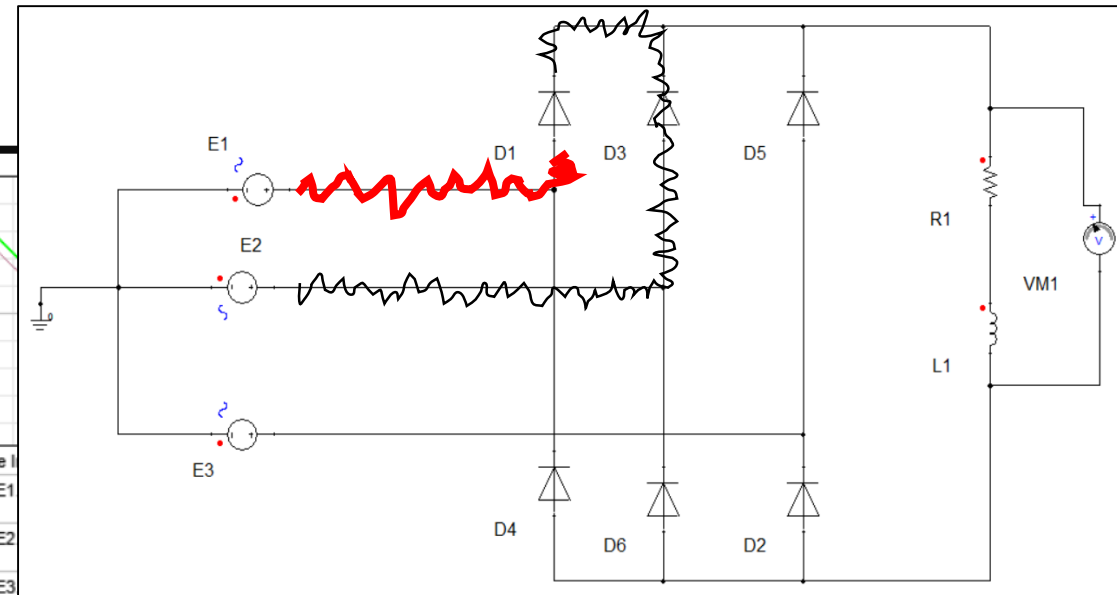
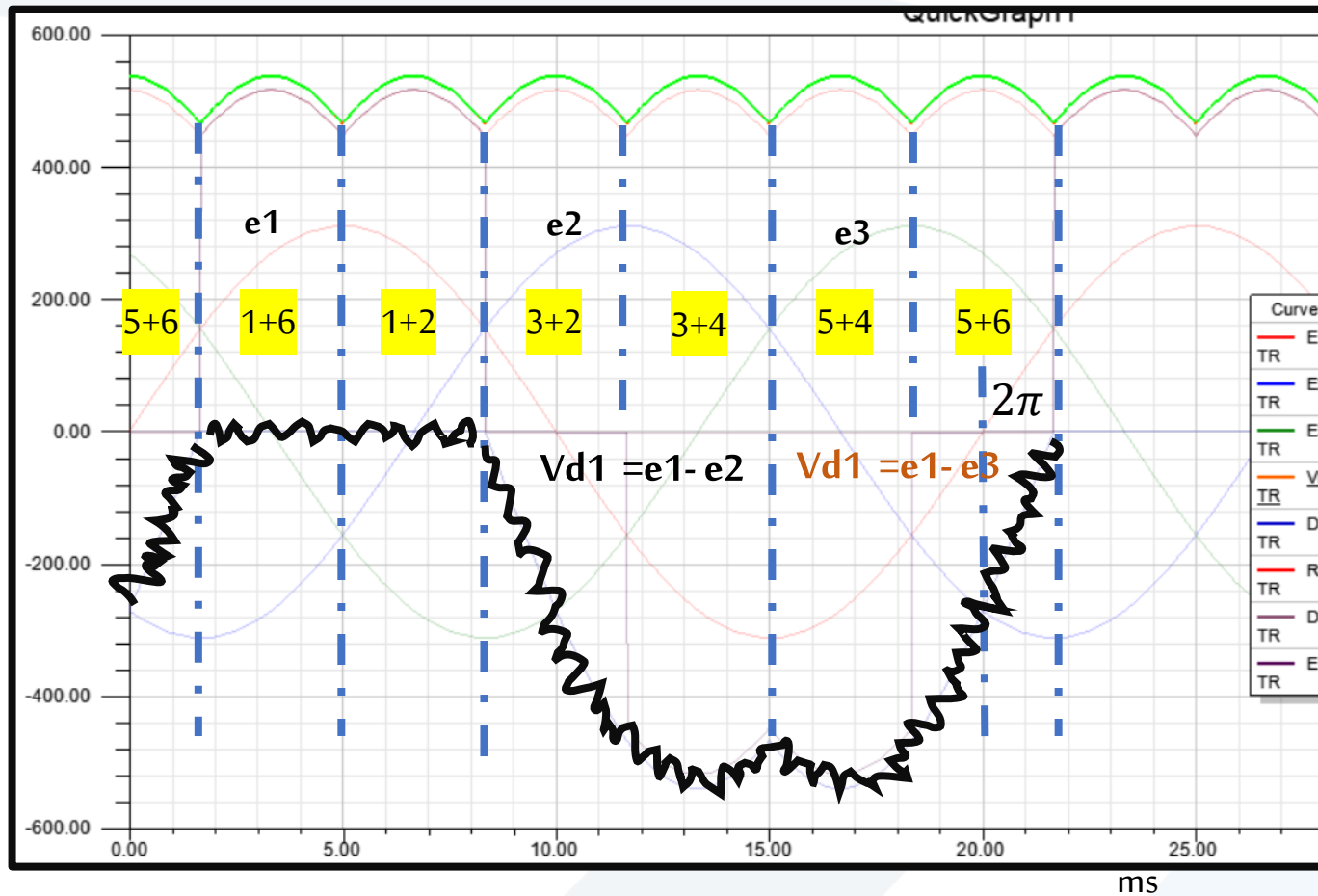
Peak inverse voltage (PIV)

جهد العكسي للديود الاول

D3 is on $\Rightarrow V_{d1} = e_1 - e_2$

D1 is on $\Rightarrow V_{d1} = 0$

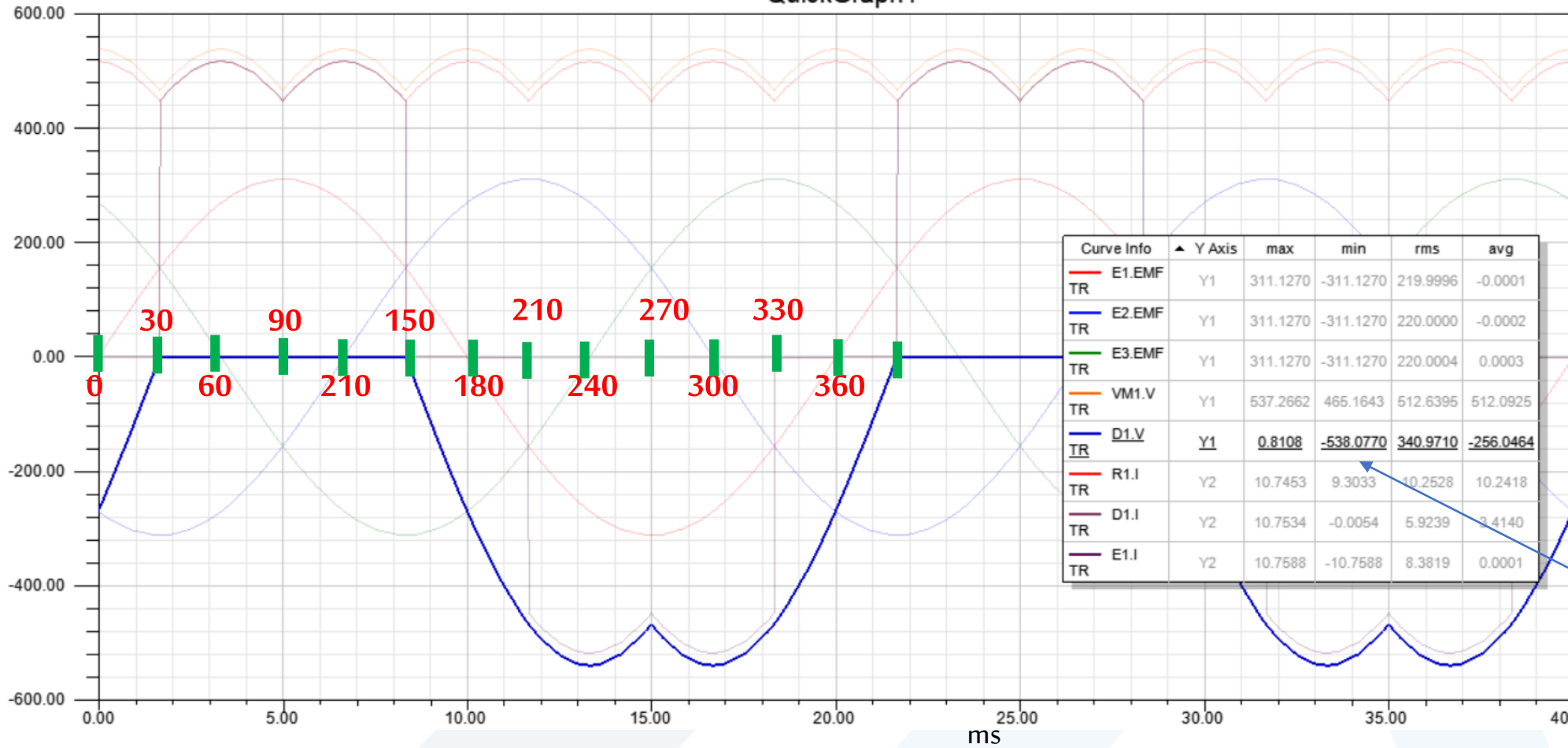
D5 is on $\Rightarrow V_{d1} = e_1 - e_3$



Peak inverse voltage (PIV)







جهد العكسي للديود الاول

QuickGraph1



$$V_{DRMAX} = -\sqrt{3}U_{2m}$$

U_{2m}

Curve Info	▲ Y Axis	max	min	rms	avg
 E1.EMF TR	Y1	311.1270	-311.1270	219.9996	-0.0001
 E2.EMF TR	Y1	311.1270	-311.1270	220.0000	-0.0002
 E3.EMF TR	Y1	311.1270	-311.1270	220.0004	0.0003
 VM1.V TR	Y1	537.2662	465.1643	512.6395	512.0925
 D1.V TR	Y1	0.8108	-538.0770	340.9710	-256.0464
 R1.I TR	Y2	10.7453	9.3033	10.2528	10.2418
 D1.I TR	Y2	10.7534	-0.0054	5.9239	3.4140
 E1.I TR	Y2	10.7588	-10.7588	8.3819	0.0001

$$U_{L_{rms}} = 1.655U_{2m}$$

$$U_{L_{av}} = 1.654U_{2m}$$

$$I_{L_{rms}} = 1.655 \frac{U_{2m}}{R}$$

$$I_{L_{av}} = 1.654 \frac{U_{2m}}{R}$$

$$I_{D_{av}} = \frac{I_{L_{av}}}{3} = \frac{1.654 \frac{U_{2m}}{R}}{3}$$

$$I_{D_{rms}} = \frac{I_{L_{rms}}}{\sqrt{3}} = \frac{1.655 \frac{U_{2m}}{R}}{\sqrt{3}}$$

$$I_{S_{rms}} = \frac{\sqrt{2}I_{L_{rms}}}{\sqrt{3}} = \frac{\sqrt{2}}{\sqrt{3}} 1.655 \frac{U_{2m}}{R}$$

Parameters - L1 - Inductor

Parameters | Output / Display

Name Show Name

Parameters

Inductance Use Pin
Value, Variable, Expression

Nonlinear
 $i = f(\psi)$ Use Pin

Nonlinear
 $L = f(i), dL/dt = 0$ Use Pin

Initial Value

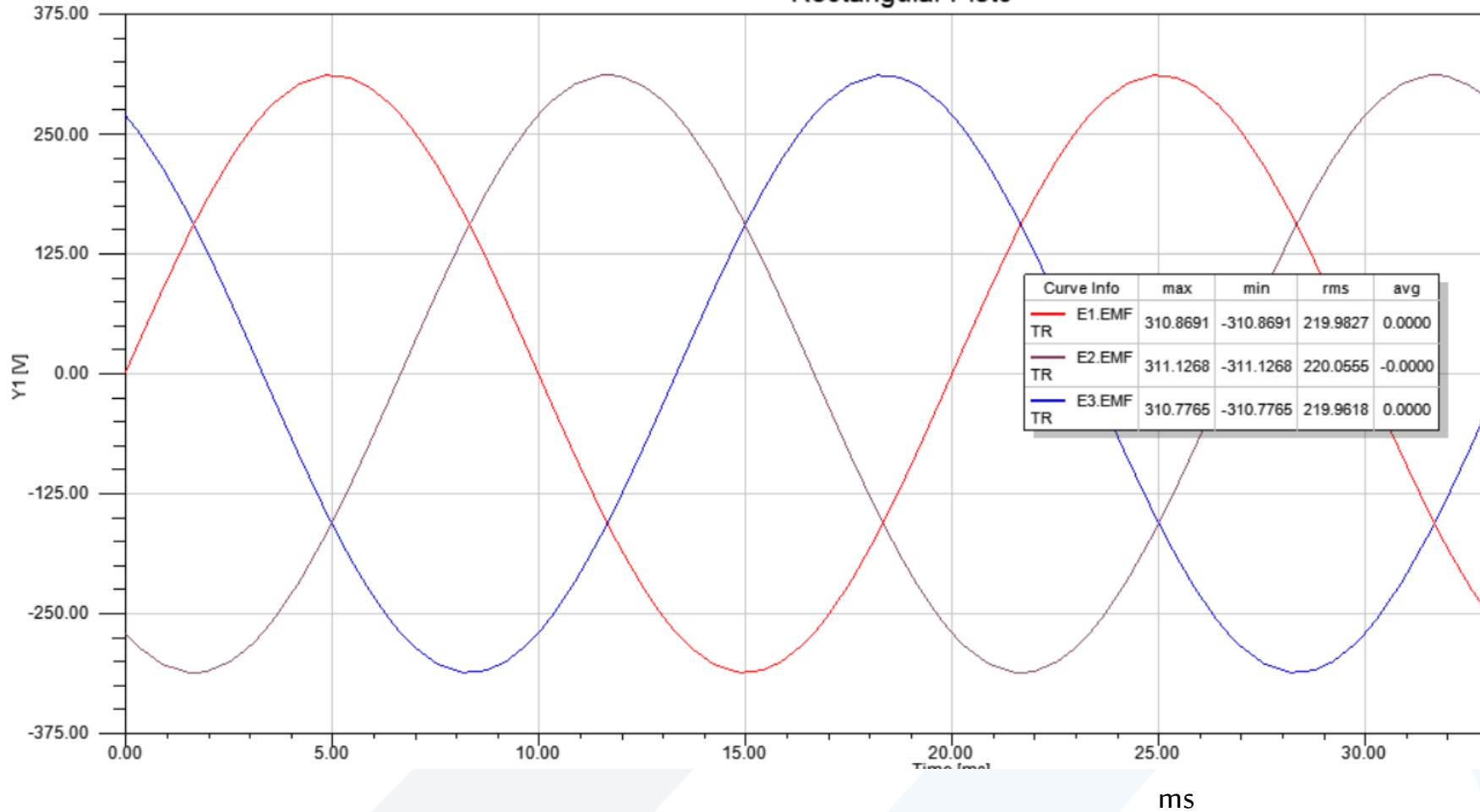
Initial Value

Outputs

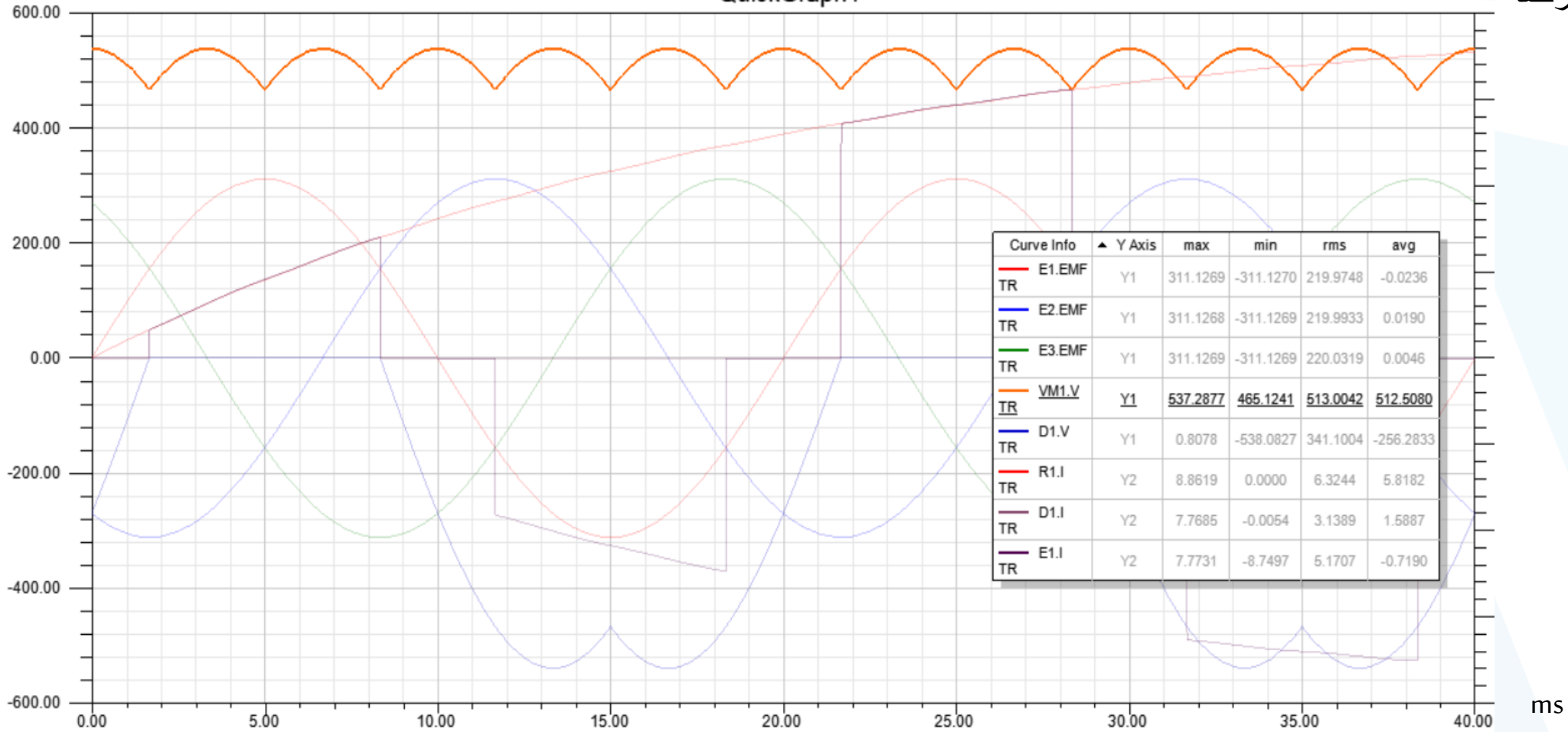
Voltage Current Inductance

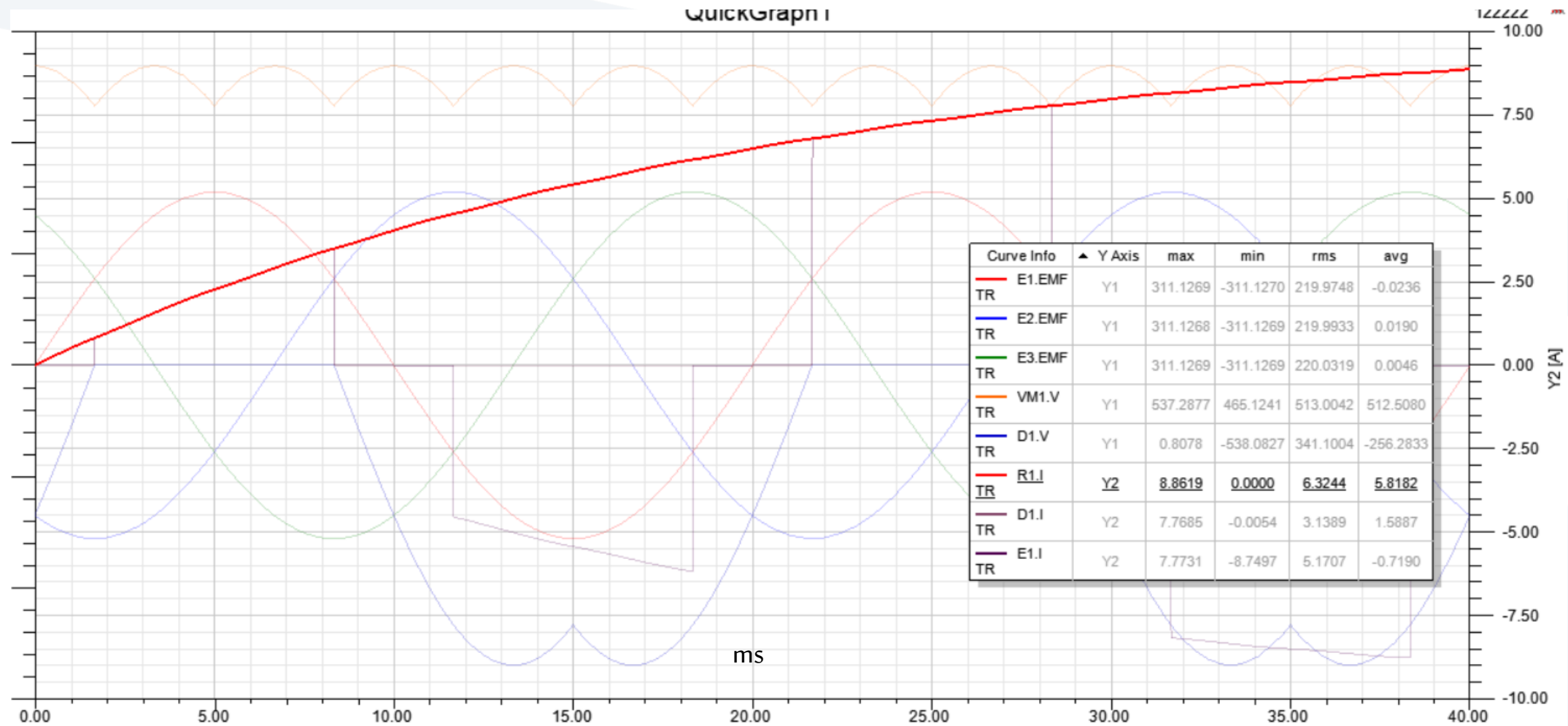
OK Cancel

Rectangular Plot0



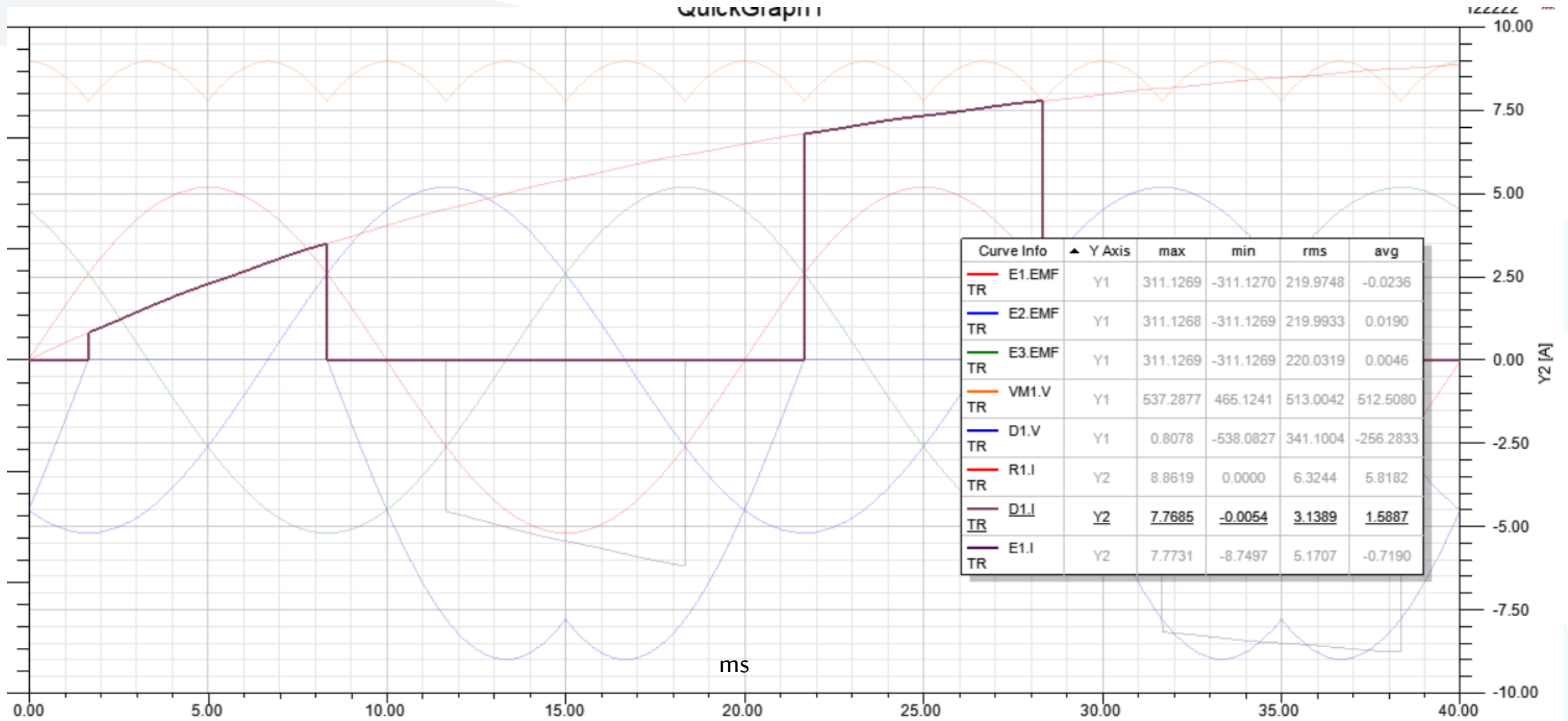
QuickGraph1



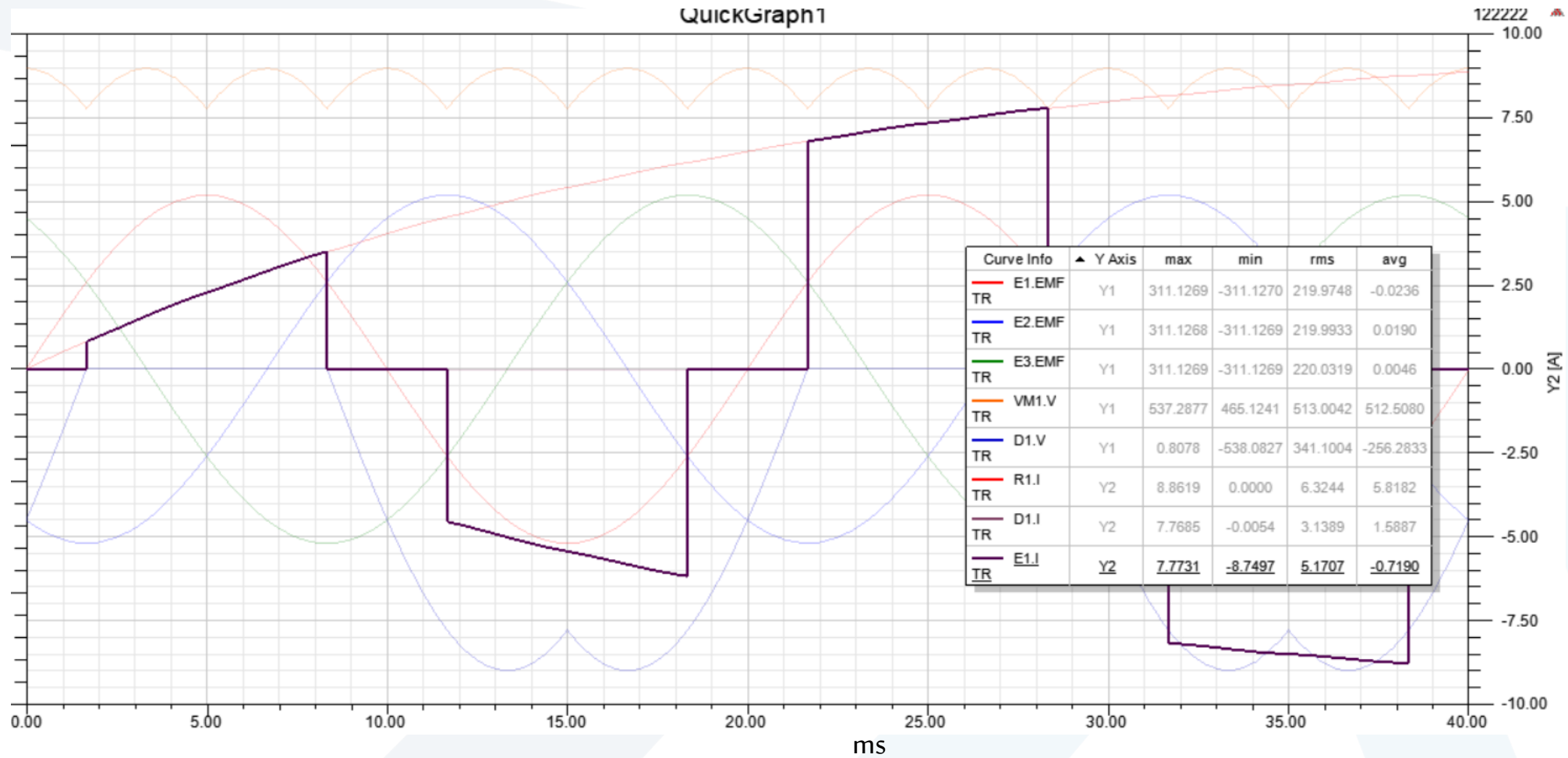


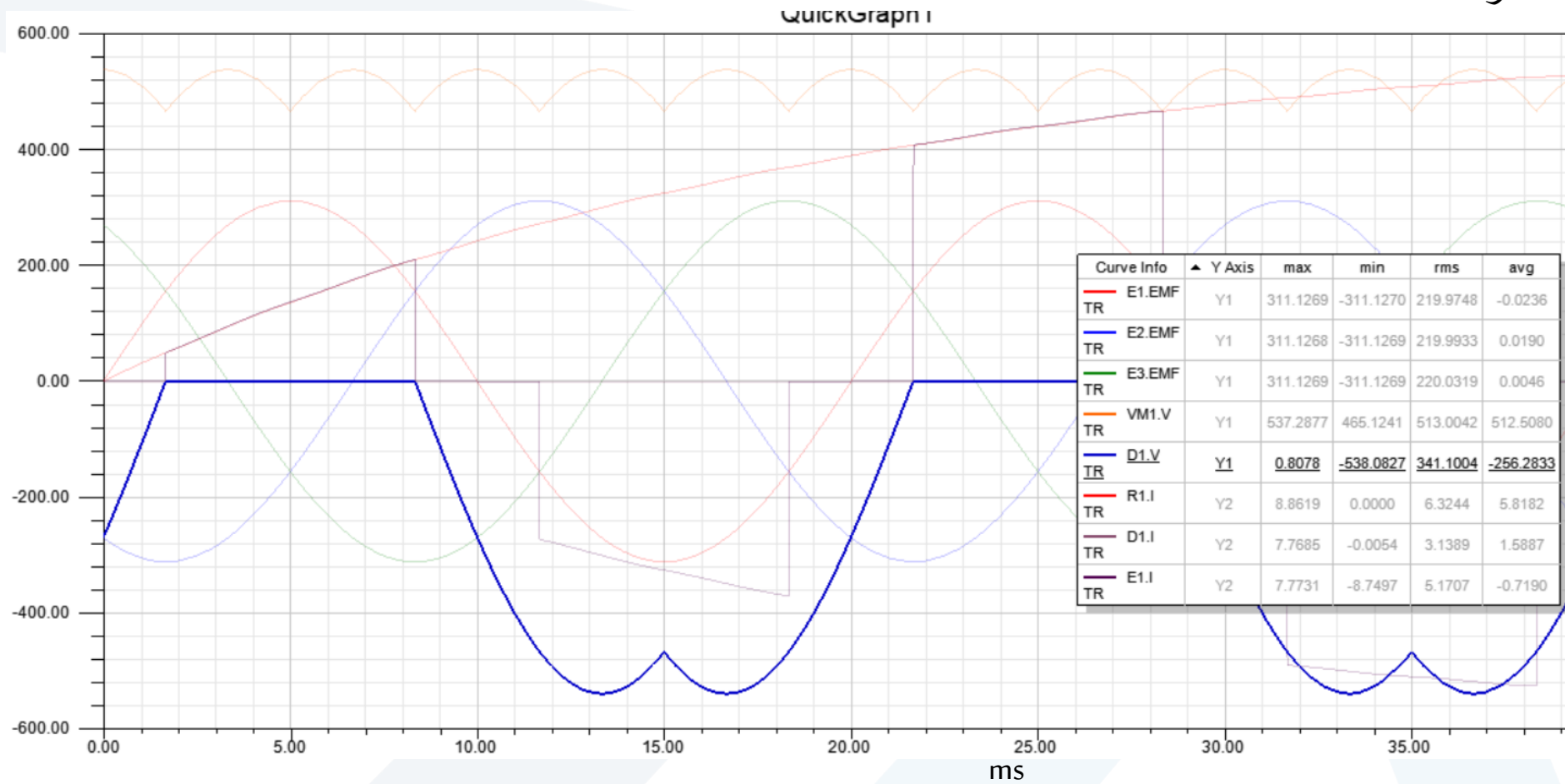


QuickGraph



QuickGraph1







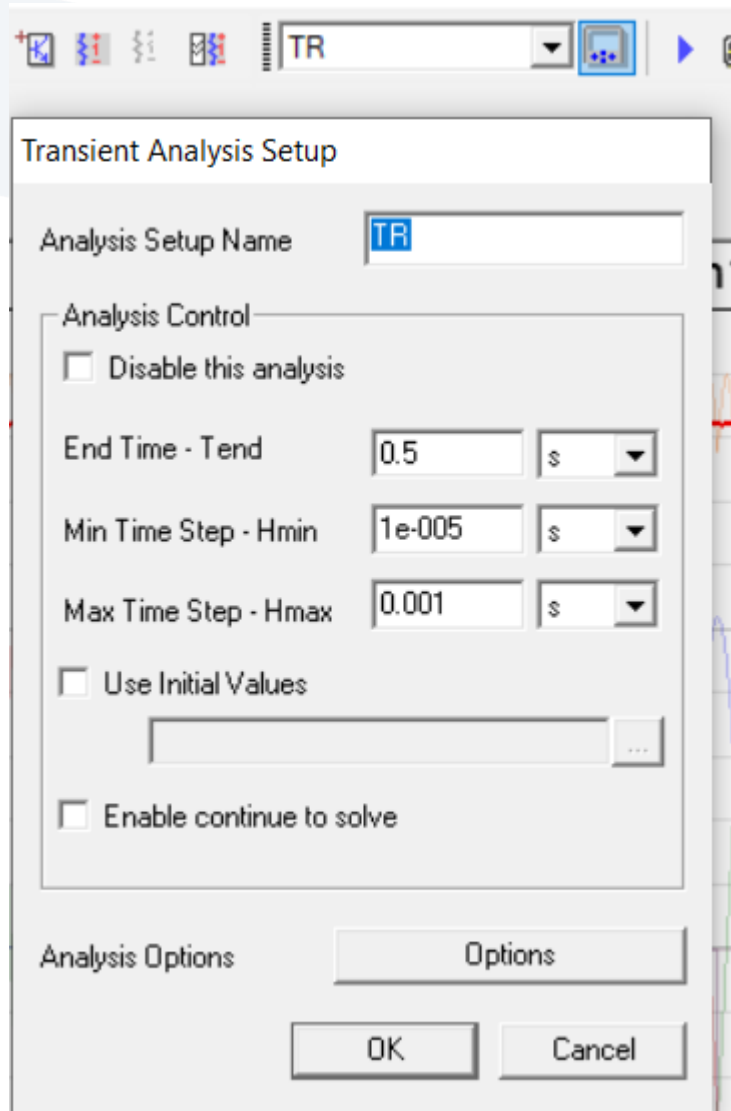
Curve Info	▲ Y Axis	max	min	rms	avg
TR E1.EMF	Y1	311.1269	-311.1270	219.9748	-0.0236
TR E2.EMF	Y1	311.1268	-311.1269	219.9933	0.0190
TR E3.EMF	Y1	311.1269	-311.1269	220.0319	0.0046
TR VM1.V	Y1	537.2877	465.1241	513.0042	512.5080
TR D1.V	Y1	0.8078	-538.0827	341.1004	-256.2833
TR R1.I	Y2	8.8619	0.0000	6.3244	5.8182
TR D1.I	Y2	7.7685	-0.0054	3.1389	1.5887
TR E1.I	Y2	7.7731	-8.7497	5.1707	-0.7190

بوجود المحارضة

زمن المحاكاة قليل جدا

Curve Info	▲ Y Axis	max	min	rms	avg
TR E1.EMF	Y1	311.1270	-311.1270	219.9996	-0.0001
TR E2.EMF	Y1	311.1270	-311.1270	220.0000	-0.0002
TR E3.EMF	Y1	311.1270	-311.1270	220.0004	0.0003
TR VM1.V	Y1	537.2662	465.1643	512.6395	512.0925
TR D1.V	Y1	0.8108	-538.0770	340.9710	-256.0464
TR R1.I	Y2	10.7453	9.3033	10.2528	10.2418
TR D1.I	Y2	10.7534	-0.0054	5.9239	3.4140
TR E1.I	Y2	10.7588	-10.7588	8.3819	0.0001

بغياب المحارضة



Transient Analysis Setup

Analysis Setup Name

Analysis Control

Disable this analysis

End Time - Tend s

Min Time Step - Hmin s

Max Time Step - Hmax s

Use Initial Values

...

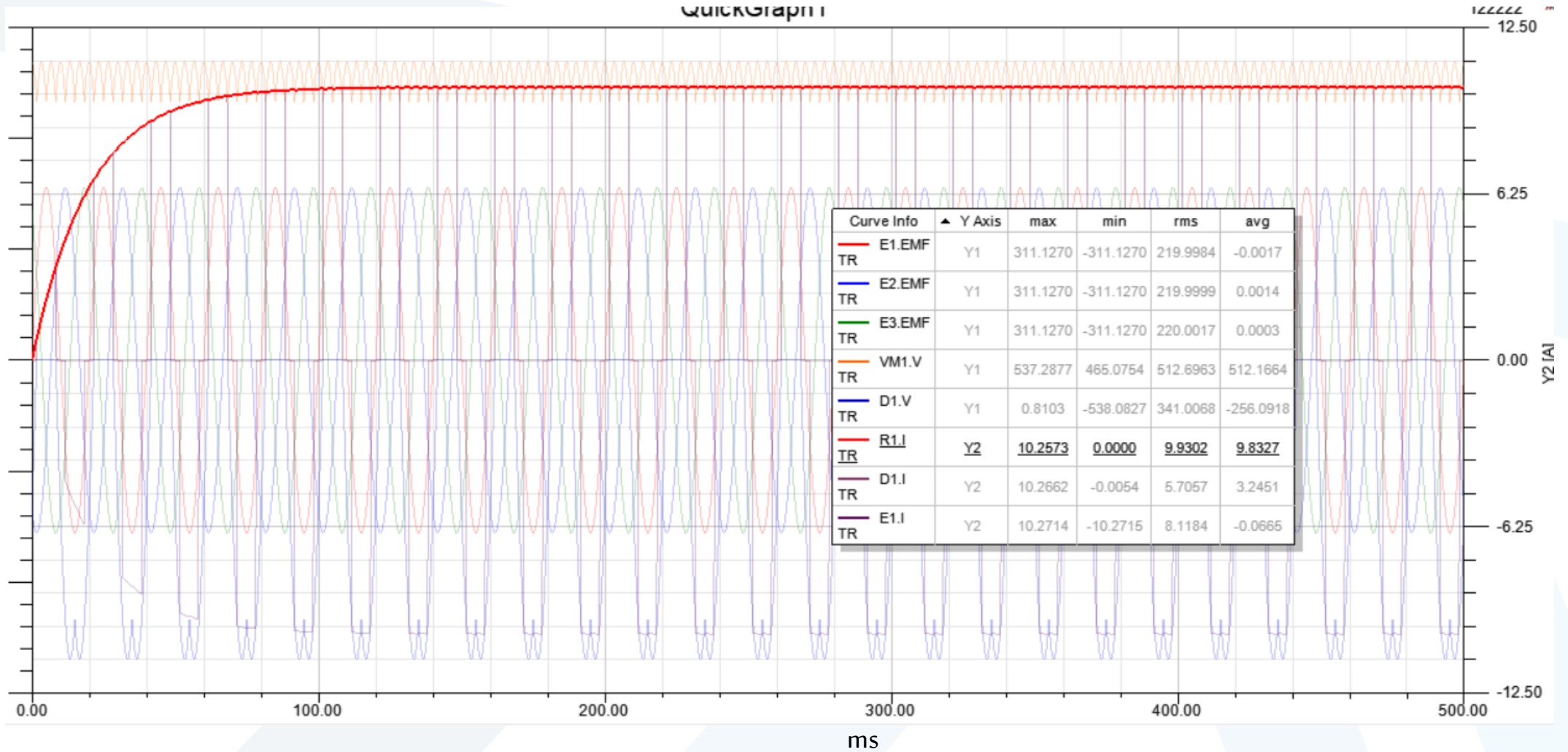
Enable continue to solve

Analysis Options



جامعة
المنارة
MANARA UNIVERSITY

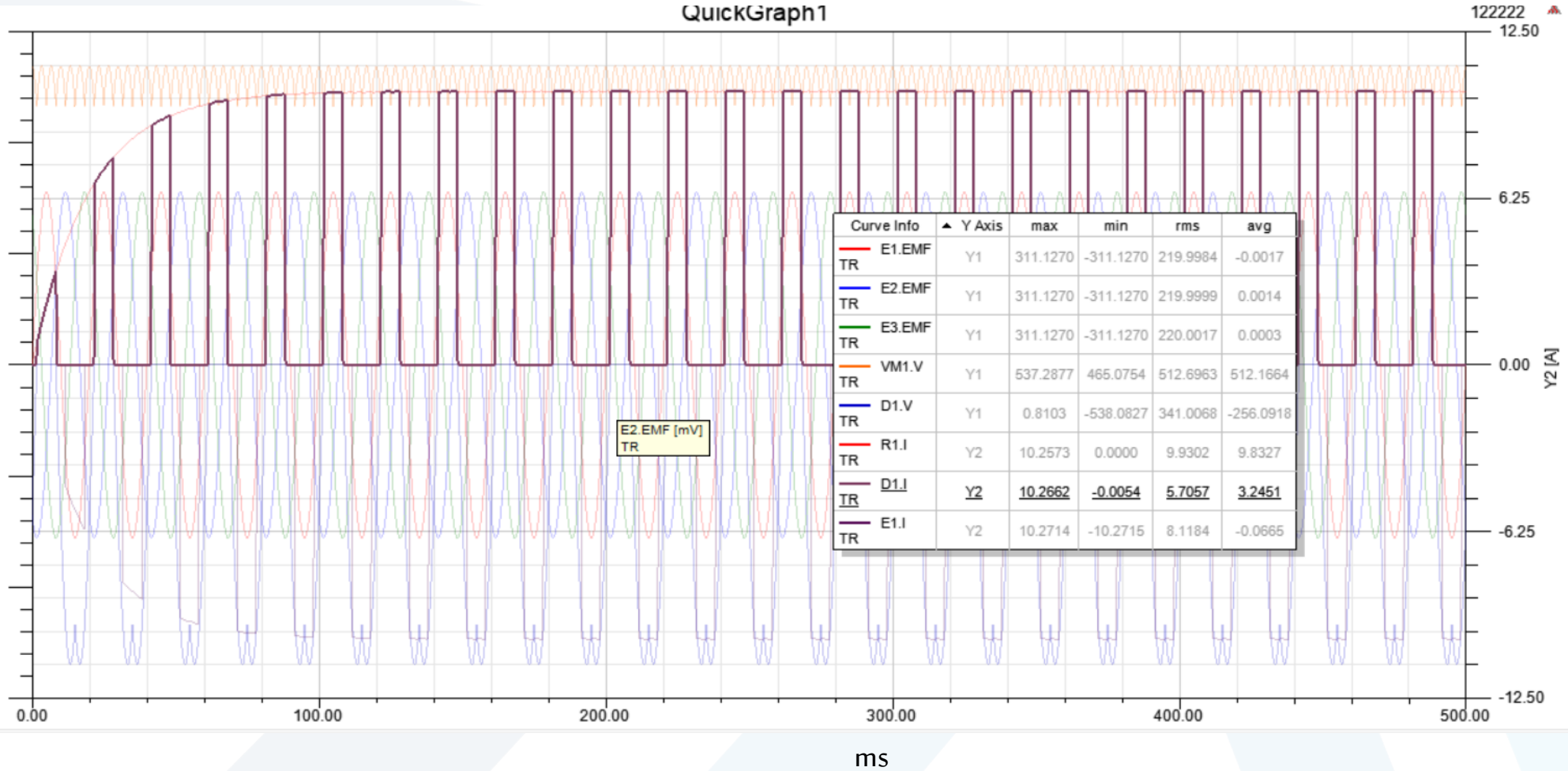
QuickGraph





جامعة
المنارة
MANARA UNIVERSITY

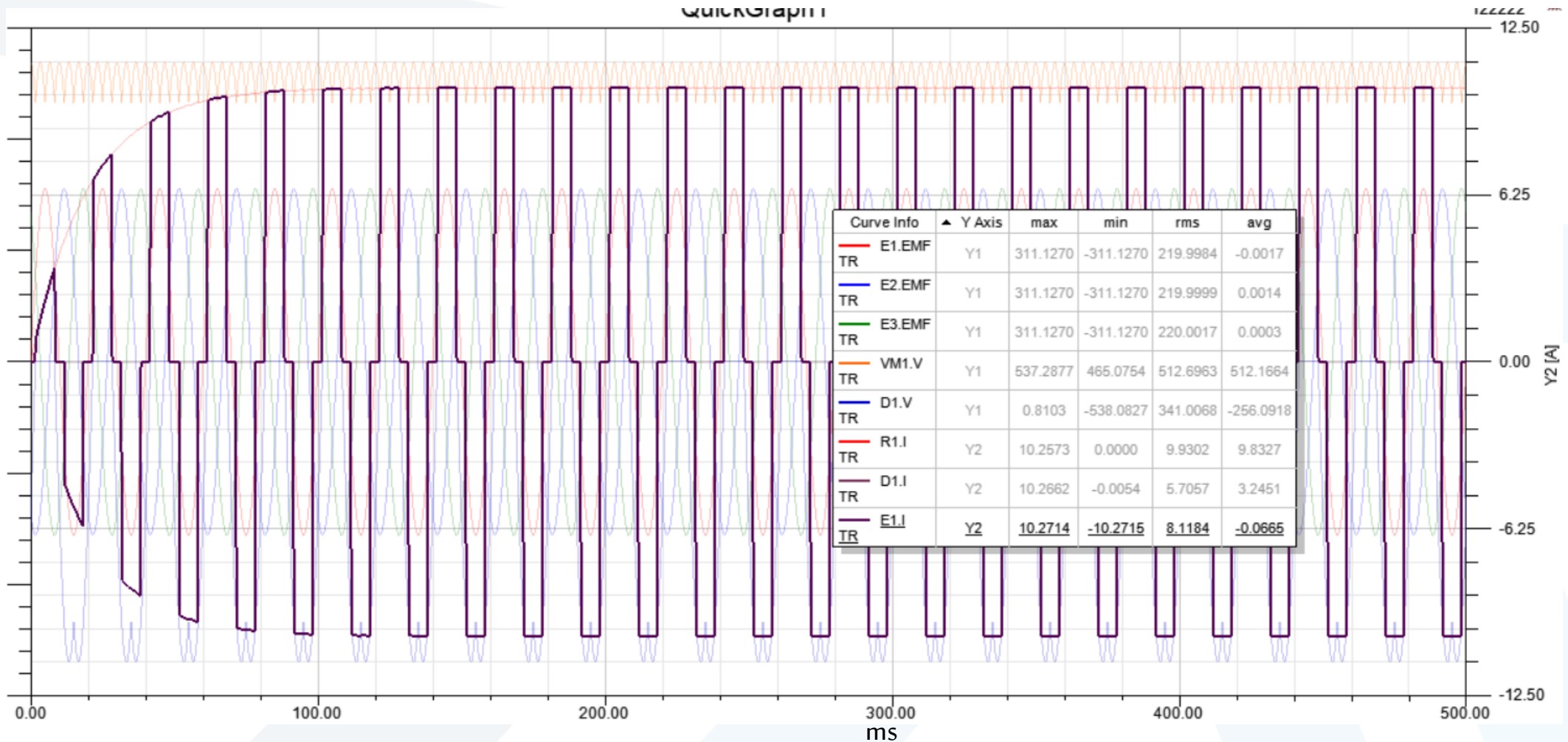
QuickGraph1





جامعة
المنارة
MANARA UNIVERSITY

QuickGraph II



Curve Info	Y Axis	max	min	rms	avg
E1.EMF TR	Y1	311.1270	-311.1270	219.9984	-0.0017
E2.EMF TR	Y1	311.1270	-311.1270	219.9999	0.0014
E3.EMF TR	Y1	311.1270	-311.1270	220.0017	0.0003
VM1.V TR	Y1	537.2877	465.0754	512.6963	512.1664
D1.V TR	Y1	0.8103	-538.0827	341.0068	-256.0918
R1.I TR	Y2	10.2573	0.0000	9.9302	9.8327
D1.I TR	Y2	10.2662	-0.0054	5.7057	3.2451
E1.I TR	Y2	10.2714	-10.2715	8.1184	-0.0665

Curve Info	Y Axis	max	min	rms	avg
E1.EMF TR	Y1	311.1270	-311.1270	219.9996	-0.0001
E2.EMF TR	Y1	311.1270	-311.1270	220.0000	-0.0002
E3.EMF TR	Y1	311.1270	-311.1270	220.0004	0.0003
VM1.V TR	Y1	537.2662	465.1643	512.6395	512.0925
D1.V TR	Y1	0.8108	-538.0770	340.9710	-256.0464
R1.I TR	Y2	10.7453	9.3033	10.2528	10.2418
D1.I TR	Y2	10.7534	-0.0054	5.9239	3.4140
E1.I TR	Y2	10.7588	-10.7588	8.3819	0.0001

$$U_{L_{rms}} = 1.655U_{2m}$$

$$U_{L_{av}} = 1.654U_{2m}$$

$$I_{L_{rms}} = 1.655 \frac{U_{2m}}{R}$$

$$I_{L_{av}} = 1.654 \frac{U_{2m}}{R}$$

$$I_{D_{av}} = \frac{I_{L_{av}}}{3} = \frac{1.654}{3} \frac{U_{2m}}{R}$$

$$I_{S_{rms}} = \frac{\sqrt{2}I_{L_{rms}}}{\sqrt{3}} = \frac{\sqrt{2}}{\sqrt{3}} 1.655 \frac{U_{2m}}{R}$$

$$I_{D_{rms}} = \frac{I_{L_{rms}}}{\sqrt{3}} = \frac{1.655}{\sqrt{3}} \frac{U_{2m}}{R}$$

انتهت المحاضرة