

The Effect of Load Resistance on uncontrolled Rectifier Performance

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Abstract

This paper presents the usefulness of the circuit simulator Multisim software moreover, the understanding the operation of full-wave single phase rectifier circuit with RC load and study the effect of the load resistance R_L on the voltage, output current were discussed , the output power, the ripple factor and the total harmonic distortion (THD). Simulation results are existing along with the theoretical analysis. It can obtain a power factor by simulated is unity, to be excellent results.

Keywords: Uncontrolled Rectifier, Multisim software, THD.

1- Introduction

An AC to DC converter is an integral part of any power supply unit used in the all-electronic equipment. Also, it is used as an interface between the utility and most of the power electronic equipment. These electronic equipment form a major part of the load on the utility. Generally, to convert line frequency AC to DC, a line frequency diode bridge rectifier is used. To reduce the ripple in the DC output voltage, a large filter capacitor is utilized at the rectifier output[1]. The ripple at the rectifier output depends on the filter and the voltage regulator (usually an integrated circuit) [2].

2-Full-wave rectifier with RC load

A single phase rectifier consists of four diodes connected in a closed loop bridge configuration so as to produce the rectified output voltage. The four diodes are connected in series pairs with only one diode pair conduct during each half cycle. The rectifier with filter capacitor is

called a conventional AC-DC utility interface which is shown in Fig. (1). The filter capacitor reduces the ripples present in the output voltage. Although a filter capacitor significantly suppresses the ripple from the output voltage, it introduces distortions to the input current and draws current from the supply discontinuously, in short pulses as shown in Fig. (2) [3,4,5].

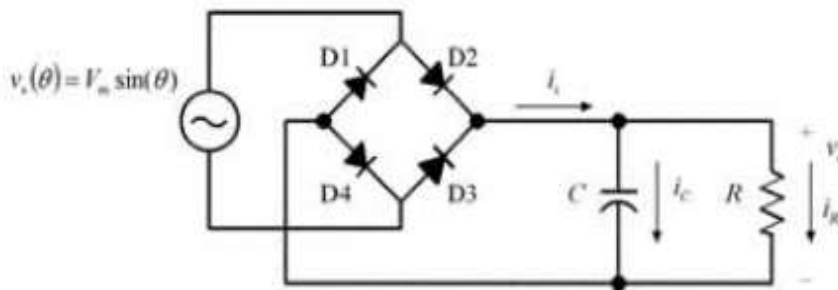


Fig.(1): Full-wave single phase uncontrolled rectifier circuit with RC load [5].

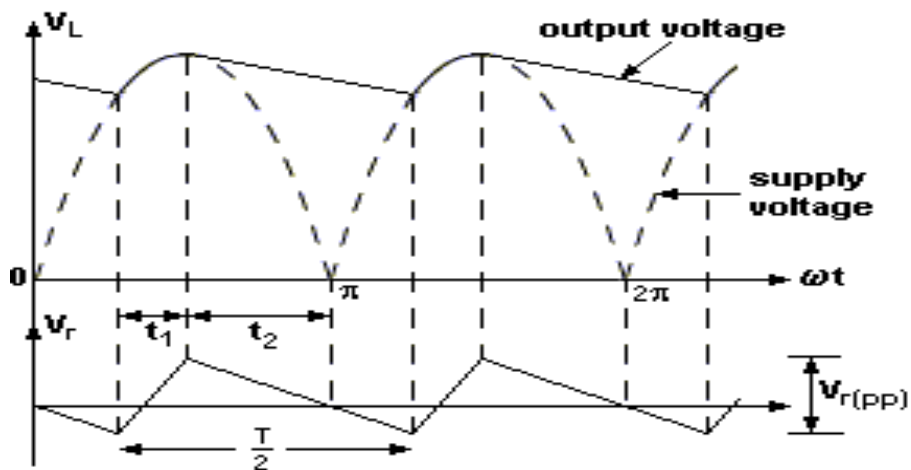


Fig.(2): Output voltage, supply voltage and ripple voltage waveforms [5].

2-1- Theoretical analysis

A simple method to analysis is to represent the average load voltage V_{dc} (DC component of load voltage V_L).The full-wave bridge rectifier circuit waveforms have a period of π rather than 2π , as shown in Fig(1) and (2). In particular, the capacitor discharges exponentially through R_L [4].

$$\frac{1}{C} \int I_L dt + V_C(t = 0) R_L I_L = 0 \quad (1)$$

where C : the capacitance of capacitor , R_L : load's resistance , I_L = load current , t : time and V_C : the capacitor voltage , which with an initial condition $V_C(t = 0) = V_m$,(V_m : peak value of voltage) gives the discharging current as [4].

$$I_L = \frac{V_m}{R} e^{-t/R_L C} \quad (2)$$

The output (or capacitor) voltage ($V_L = V_C$) , during the discharging period can be found from

$$V_L = R I_L = V_m e^{-t/R_L C} \quad (3)$$

The peak-to-peak ripple voltage ($V_{r(pp)}$) can be found from

$$\begin{aligned} V_{r(pp)} &= V_L(t = t_1) - V_L(t = t_2) = V_m - V_m e^{-t_2/R_L C} \\ &= V_m (1 - e^{-t_2/R_L C}) \end{aligned} \quad (4)$$

where

t_1 : charge time , t_2 : discharge time

Using the approximation $e^{-X} = 1 - X$ the above equation can be simplified to

$$V_{r(PP)} = V_m \left(1 - 1 + \frac{t_2}{R_L C} \right) = \frac{V_m t_2}{R_L C} \quad (5)$$

)
For large $R_L, t_1 \ll t_2$

hence $t \approx \frac{T}{2}$, T : the period time

but $T = \frac{1}{f}$, f : AC supply frequency.

$$\therefore t_2 = \frac{1}{2f}$$

$$\therefore V_{r(pp)} = \frac{V_m}{2f R_L C} \quad (6)$$

)

The fundamental frequency of the ripple voltage (output voltage) is twice that of the AC supply frequency. Therefore the DC component of load voltage V_L is V_{dc} and it is defined [4].

$$\begin{aligned} V_{dc} &= V_m - \frac{V_{r(PP)}}{2} \\ &= V_m - \frac{V_m}{4f R_L C} \end{aligned} \quad (7)$$

)

Thus the root-mean-square (rms) value of load voltage V_L is V_{rms} (the AC component of load voltage V_L) can be found approximately from[4].

$$V_{rms} = \frac{V_{r(PP)}}{2\sqrt{2}} = \frac{V_m}{4\sqrt{2} f R_L C} \quad (8)$$

)

2-2 Total Harmonic Distortion (THD)

The distortion of the normal sine wave by non-linear loads is generated by harmonics. Harmonics are linked to the fundamental frequency and are defined as total number multiples of the fundamental frequency. THD of a signal is a measurement of the harmonic distortion existing and is defined as the ratio of the amount of all harmonic components of the voltage or current waveform associated against the fundamental component of the voltage or current wave.

$$\%THD = \sqrt{\left(\frac{I_s}{I_{s1}}\right)^2 - 1} \quad (9)$$

Where I_s is the rms value of input current (Amplitude spectrum). I_{s1} is the fundamental frequency component [6,7].

2-3 The ripple factor RF

The ripple factor is a measure of the ripple content and should be greater than or equal to zero. The shape of the output voltage waveform is neared to be DC as the ripple factor tends to zero[8,9].

$$RF = \frac{1}{\sqrt{2(4fR_L C - 1)}} \quad (10)$$

3-Simulation Results

In this rectifier circuit uses input voltage ($V_{in}=12V$) and the fundamental frequency is (50 Hz) because the most equipment have worked at this input voltage. Several of researchers have been studied the value change of the capacitor but in this paper the resistance value R_L is changed from $1K\Omega$ to $5K\Omega$ and it fixed value of the filter capacitor at ($C = 10\mu F$) as shown in Fig.(1) and (2). Tables(1) to (3) show results of voltage, current, power factor and output power are obtained from the simulation using the Multimeter and the Oscilloscope which can be seen in Figs.(3) and (4).

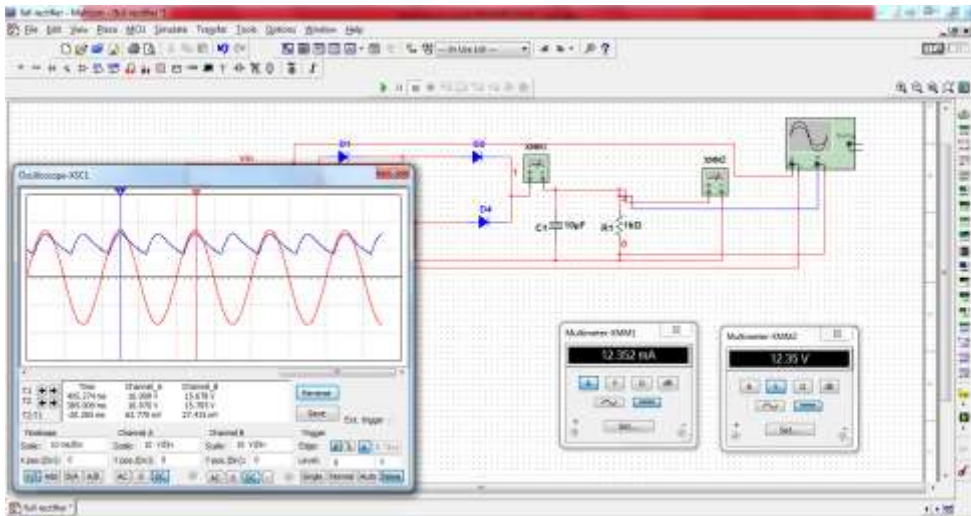


Fig.(3): Simulation Full-wave rectifier circuit with R_L C load by multisim software shows the value current and voltage output.

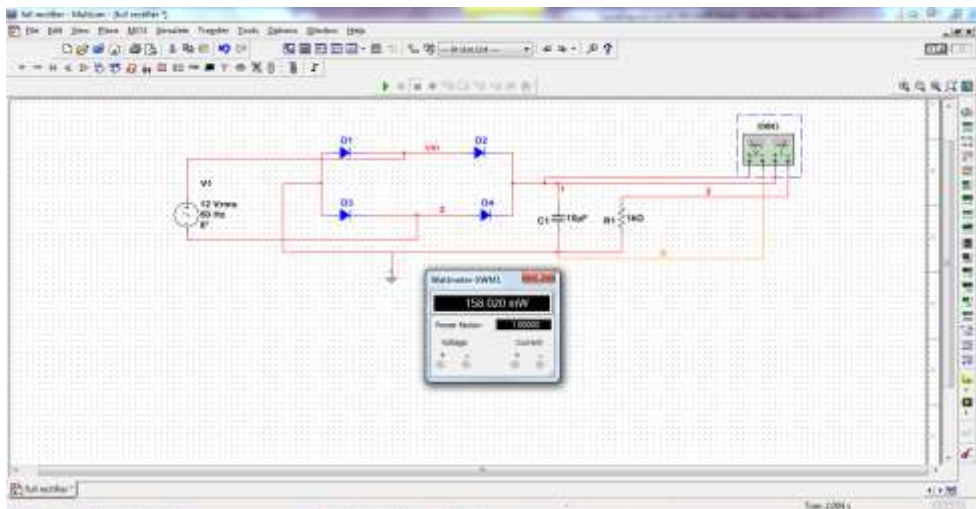


Fig.(4): Simulation Full-wave rectifier circuit with R_L C load by multisim software shows output power and power factor.

The capacitor filter supplies used goes a smooth DC output voltage in case the filter capacitor value is large , it can be seen in Figs.(3) and (4) . When the negative part input to the capacitor, it begins discharging into the load. The rate of discharge is determined by the time constant $R_L C$ is formed by the capacitor and the load's resistance ($\tau = R_L C$). The pulsating output shown in Fig. (5) is greater than that illustrated in the Fig.(6). Therefore the ripple voltage in Fig.(5) is greater than in Fig.(6). This' leads to Increase the time constant τ from 10 milliseconds to 50 milliseconds, which give the best results with less ripple at ($R_L = 5K\Omega$).

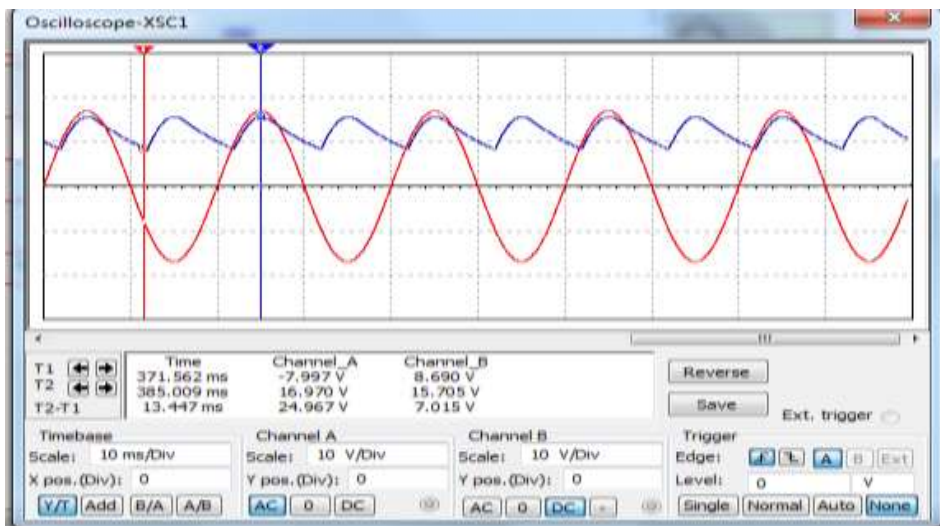


Fig.(5) : Input and output voltage at $R_L = 1K\Omega$ and $C = 10\mu F$.

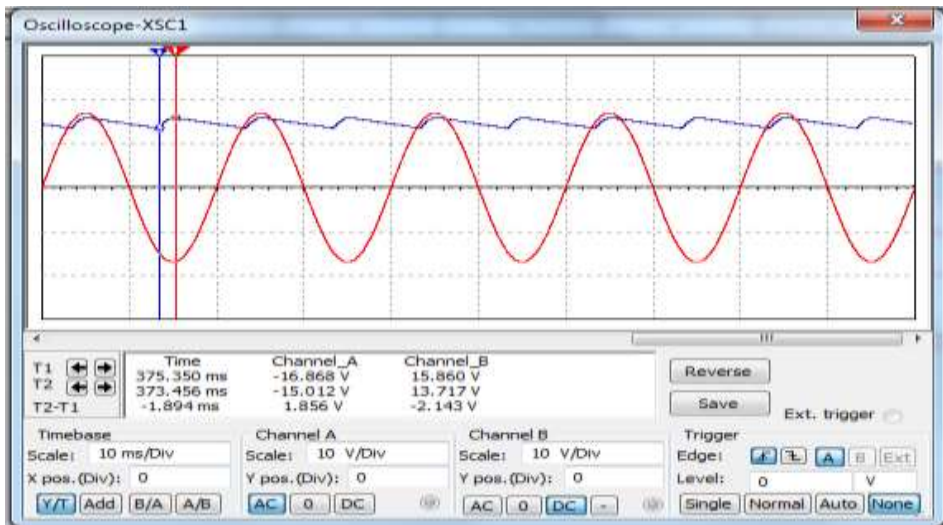


Fig.(6): Input and output voltage at $R_L = 5K\Omega$ and $C = 10\mu F$.

It is possible to calculate the average output voltage V_{dc} theoretically from the Equation (6) , to substitute the values of load resistor ($R_L = 1000\Omega$), capacitance of capacitor ($C = 10\mu F$) output frequency ($f=100$ Hz) and peak value ($V_m = 15.8 V$).The theoretical and simulation results agree well, it is illustrated in Fig.(7).

Table(1): Noted Values via Multisim Simulation

$R_L k\Omega$	$C \mu F$	V_m	$I_{dc} mA$	$I_{rms} mA$
1	10	15.8	12.3	17.5
2	10	15.8	6.8	12
3	10	15.8	4.7	9.3
4	10	15.8	3.6	7.7
5	10	15.8	2.9	6.6

Table(2): Output Voltage by Theory and Simulation.

R_L k Ω	V_{dc} V		V_{rms} V	
	Simulation	theoretical	simulation	theoretical
1	12.3	11.85	2.3	2.8
2	13.6	13.845	1.47	1.4
3	14.1	14.48	1	0.93
4	14.5	14.8	0.854	0.7
5	14.7	15	0.707	0.55

Table (3): Summary Ripple Voltage and Ripple Factor

R_L k Ω	C μ F	$V_{p.p}$ V		RF	
		simulation	theoretical	simulation	theoretical
1	10	7	7.9	0.18	0.23
2	10	4.68	3.95	0.1	0.1
3	10	3.4	2.6	0.07	0.06
4	10	2.76	2	0.058	0.047
5	10	2.3	1.58	0.048	0.037

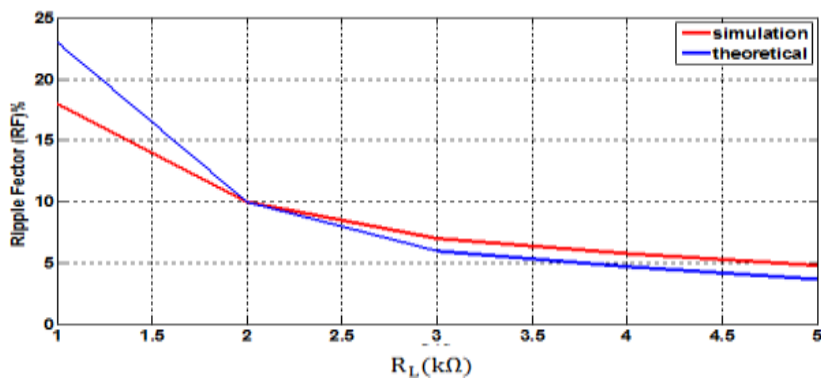


Fig (7) Ripple factor Vs load's resistance.

Fig.(8) shows input and output voltage at load resistor ($R_L = 1K\Omega$) . It is noticed from the figure that the kind of current of the single phase diode bridge rectifier with capacitive load turns out to be peaky in kind .

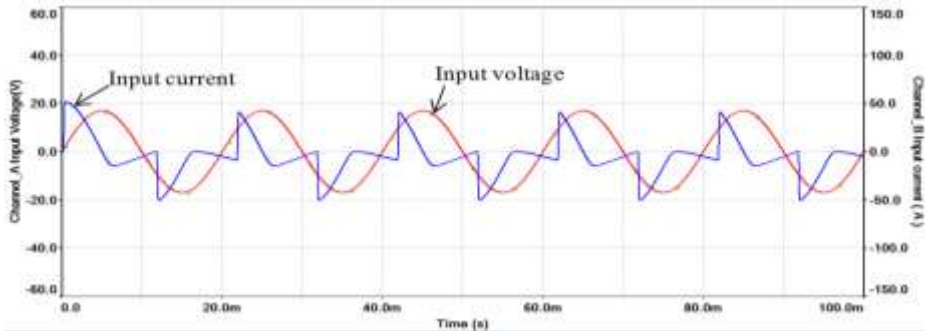


Fig.(8) : Input current and input voltage for bridge rectifier circuit.

The THD and output power, P_{out} reading for various values of R_L by simulating the circuit ,the recorded values are tabulated in Table(4).Using the Fourier analysis, there is a clear effect on the THD, with the increase values of the load resistance. It is seen that simulation results of the circuit have a unity PF for any value of the R_L .

Table (4) : Variation of total harmonic distortion (THD), output power and power factor of various load resistances via multisim simulation

$R_L k\Omega$	C μF	THDi%	PF	$P_{out} mW$
1	10	76.6	1	95.5
2	10	101.2	1	66.9
3	10	115.7	1	52.7
4	10	125.9	1	43.6
5	10	133.5	1	37.2

Using simulation, we obtained from Fourier analysis of computation the total harmonic distortion of the input current from $R_L = 1k\Omega$ to $R_L = 5k\Omega$ as well as we had got on amplitude spectrum representing

the relationship between harmonic frequency and amplitude current is shown in Figs. (9) and (10) .

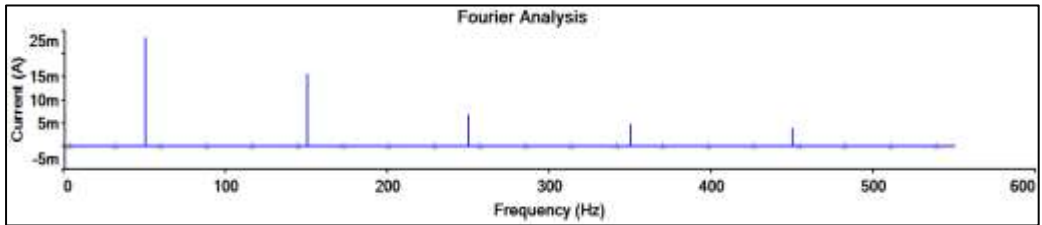


Fig.(9) : Amplitude spectrum of input current at $R_L = 1K\Omega$.

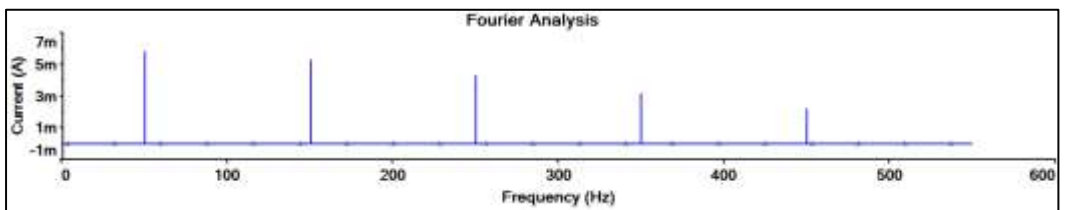


Fig.(10) : Amplitude spectrum of input current at $R_L = 5K$.

To confirm the results presented previously, the Fig. (11) and (12) were used .

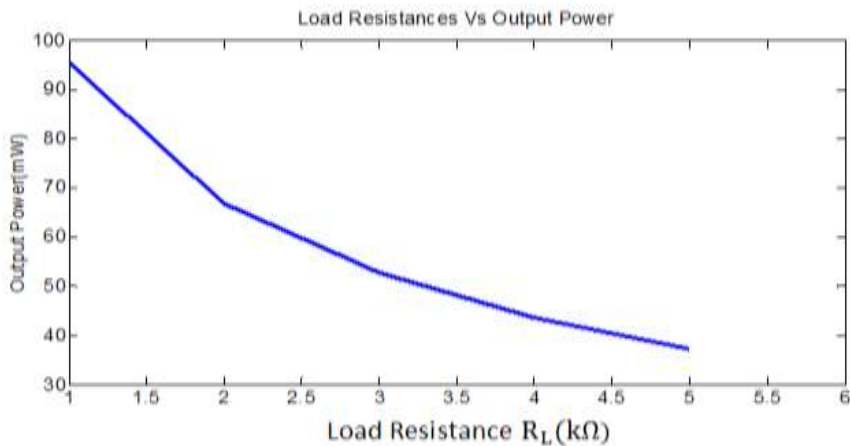


Fig. (11) : Load resistance Vs output power.

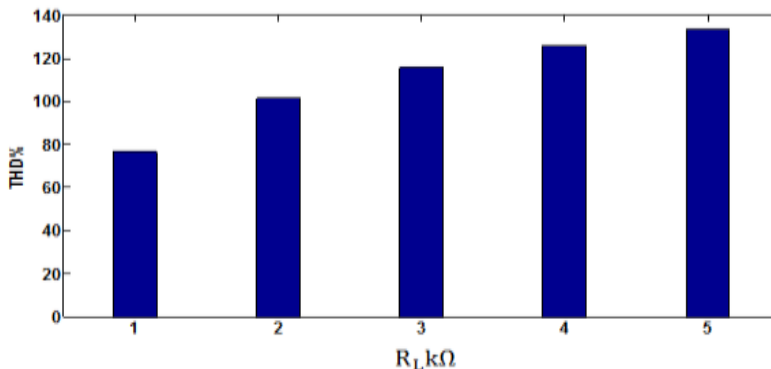


Fig. (12): Total harmonic distribution of input current as load resistance.

4- Discussion

The results of this paper showed that there is a correlation between the resulting values of simulation, theoretical values and so that this is consistent with the observation of [V.dpatel et al][9,10]. The existence of the capacitor contiguous parallel with the resistance led to an increase the DC component of the output voltage and meaningfully decreases the output ripple voltage which is agreed with [R. Sbaffer][5]. While a filter capacitor significantly crushes the ripple for the output voltage, it involving distortions in the input current and draws current due to the supply discontinuously, in short pulses is resembled according to [H. Anga et al] [3]. The variation of THD and its Output power P_{out} due to the variation of load resistance, it has explained of the high THD to be agree with low P_{out} . The circuit have a unity PF, while other research shows that the power factor is less than unity. I think due to the large value to load resistance is compared with capacitor.

5-Conclusions

The results obtained from the simulations were calculated by the use of the Multisim program for the circuit of the rectifier and a clear relationship was found between the readings from the simulation and the theoretical results. This is a proof that the simulation program is

characterized by great confidence. The study showed that the change in the load resistance R_L values gave the same results when the change by the amplitude increasing the values of the time constant of expansion which caused an increase in the average value of the output voltage V_{dc} and reduce the effect of the alternating voltage of the output voltage V_{rms} .

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تأثير مقاومة الحمل على اداء المقوم غير المحكم

م. علي نثير طعيمة

قسم الفيزياء / كلية العلوم / جامعة ذي قار

الملخص

يلخص هذا البحث الاستفادة من برنامج المحاكاة الدوائر Multisim software في فهم عمل مقوم موجة كامل احادي الطور غير محكم متصل بحمل RC و دراسة تأثير مقاومة الحمل على جهد وتيار الخرج, قدرة الخرج, عامل التموج, والتشويه والتوافقي الكلي THD. وجد تطابق كبير بين النتائج المحاكاة والجانب النظري, حيث ان عامل القدرة الخرج للدائرة يساوي واحد باستخدام المحاكاة.

الكلمات المفتاحية :- مقوم , محاكاة , برنامج Muiltsim , THD , عامل التموج.