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Report for Experiment #8

AC & DC Power Analysis and Design

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Abstract:-

The aim of experiment

The experiment was done to examine Ac &Dc circuit power analysis and maximum power transfer ,the resistive load and inductive load circuit was connected , the resistive load power was measured ,one time using the product of the voltage on the load and the current crossing it ,second time using wattmeter ,the inductive load power and power factor was calculated using measured value ,also, the value of capacitor that needed to correct the power factor was measured, Moreover, A load was designed so that consumes maximum power from a given circuit .

Table of Contents

Theory:-

Before defining the power factor, there are some other terms, which should be defined. Those, will lead us back to the meaning of the power factor.

KW is the working power, (Called: Actual, Active, or, Real Power) it is what actually powers our equipment and performs useful work.

KVAR is the reactive power, and it is the power essential and used for producing the magnetic flux.

KVA is the apparent power.

Now, we get back to the power factor. Power Factor(P.F.) is the ratio of working power to apparent power…..(1)

$$Pf = \frac{KW}{\sqrt{KW^2 + KVAR^2}} = \frac{P_{av}}{P_a} \ also\ Pf = Cos(\theta_v - \varphi_i)$$

This relationship between these types of power and the power factor are illustrated in the Power Triangle of figure 1

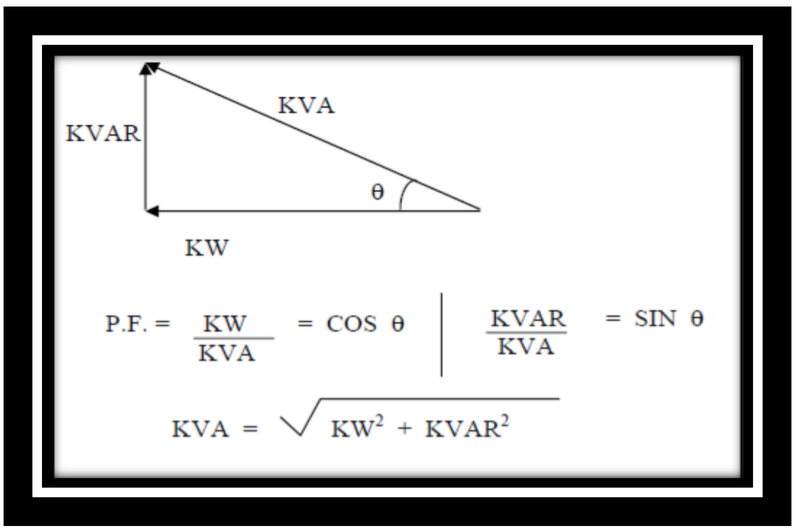

Figure 1

Note:

-KVAR would be very small.

-KW and KVA would be almost equal

-The Angle θ (formed between KW and KVA) Would approach zero

-Cosine θ would then approach one

-Power Factor Would Approach one

Since power factor is defined as the ratio of KW to KVA, we see that low power factor results when KW is small in relation to KVA. This is cause due to inductive loads.

Some of these inductive loads are:

1) Transformers

2) Induction Motors

3) Induction Generators(wind mill generators)

4) High intensity discharge (HID)lighting

Power Factor Correction:

Power factor correction comes with many benefits, and these include:

1) Lower Power utility

2) Increased capacity and losses in the system

3) Increased Voltage levels, yet cool high efficiency motors.

However increasing power factor can be done by:

1) Installing Capacitors , thus minimizing operation of idling or highly loaded motors

2) Avoiding operation of equipment above its rated voltage.

The maximum power transfer theorem plays the big part in the phase of system design, more than its role in system analysis. Simply, this theorem states that the maximum power is dissipated when the load resistance is equal to the thevenin/Norton equivalent resistance of the power supplying network. If the load is higher or lower the dissipated power will be less….. (1)

$$R_{load} = R_{th}$$

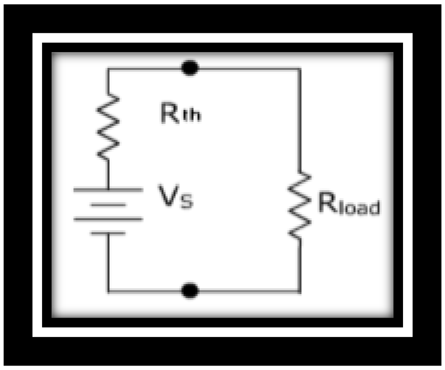

Figure 2

The efficiency factor is defined to be the percentage ratio of the output power to the input power generated by the source.

$$\text{Efficiency}(\%) = \frac{P_{out}}{P_{in}} \times 100$$

Maximum power is delivered to the load when $R_{load}=R_{int}$, therefore, the efficiency would be equal to 50 percent.

For the sinusoidal steady state:

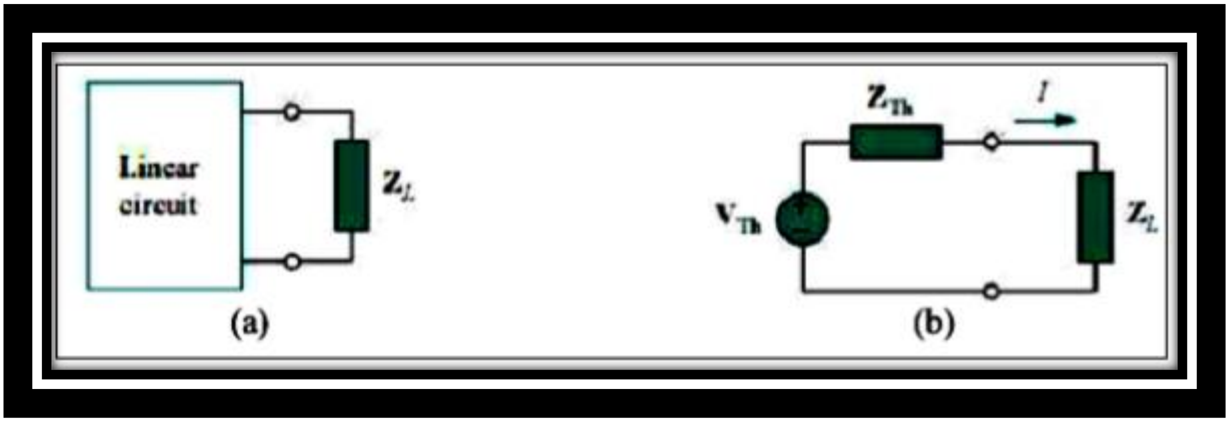

Figure 3

Figure 3: Finding maximum average power transfer: (a) circuit with a load, (b) Thevenin equivalent

If we Consider the Circuit in Figure 3, we can see an AC circuit that is connected to a load ZL and is represented by its thevenin equivalent, we usually represent the load by an impedance, it can represent anything from electric motors, to antennas and TVs. In rectangular or Cartesian form the thevenin impedance Zth and the load impedance ZL are….. (1)

Zth=Rth+jXth.

ZL=RL+jXL.

And so the current through the load is:

$$\boldsymbol{I} = \frac{\boldsymbol{V_{TH}}}{\boldsymbol{Z_{TH}} + \boldsymbol{Z_L}} = \frac{\boldsymbol{V_{TH}}}{\left((\boldsymbol{R_{TH}} + \boldsymbol{j}\boldsymbol{X_{TH}}) + (\boldsymbol{R_L} + \boldsymbol{j}\boldsymbol{X_L})\right)}$$

The average power delivered to the load is

$$P = \frac{1}{2}|I|^2 R = \frac{|Vth|^2 (RL/2)}{(Rth + RL)^2 + (Xth + XL)^2}$$

Our aim is to maximize P by adjusting the load parameters RL and XL , to do this we can take partial derivatives with respect to RL and XL ($\frac{\partial P}{\partial R}, \frac{\partial P}{\partial XL}$=0) and so after solving we get to the result that XL=-Xth, and

$RL=\sqrt{\text{Rth2} + (\text{Xth} + \text{XL})2}$

Combining all of these results leads us to a conclusion that the Maximum average power transfer ZL must be selected so that XL=-Xth and RL=Rth $ZL=RL+jXL=RTh-jXTh=ZTh*$ which means that the load impedance ZL must be the complex conjugate of the thevenin Impedance Zth…… (1)

Procedure:-

Part A: DC power measurement

The circuit in the figure 4 was connected using variable DC voltage and 1KΩ resister

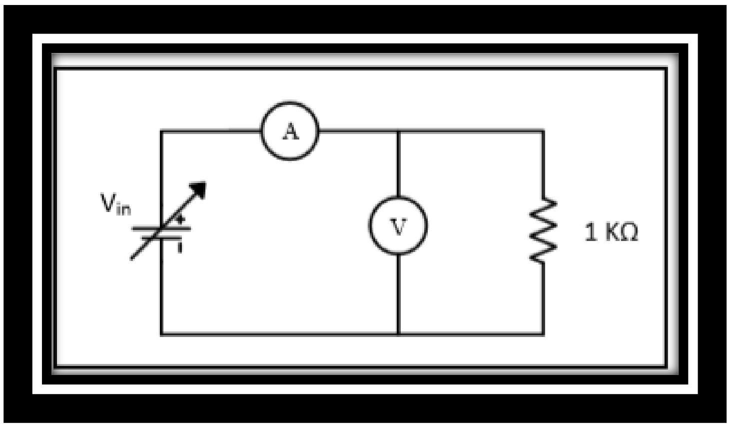

Figure 4

In each value of input voltage ,the value of the current across the resister was measured and recorded in table 1 and the real power was calculated using the measured value .

Part B: Maximum DC power transfer

The circuit in the Figure 5 was connected using Dc power supply and variable resistor.

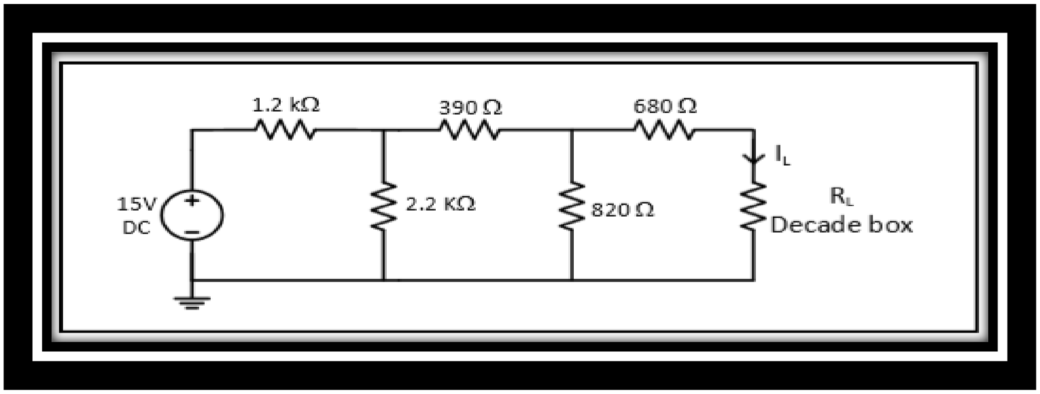

Figure 5

In each value of variable resistor ,the value of the voltage and the current across the resister was measured and recorded in table 2 and the real power was calculated using the measured value ,the equivalent resistance seen by the variable resistor was measured using DMM when the input voltage set to zero(short).

Part C: Power factor measurement

The circuit in the Figure 6 was connected using Ac supply with $V_{p\text{-}p}$=8V and frequency 1KHz ,also the inductor and resistor was used .

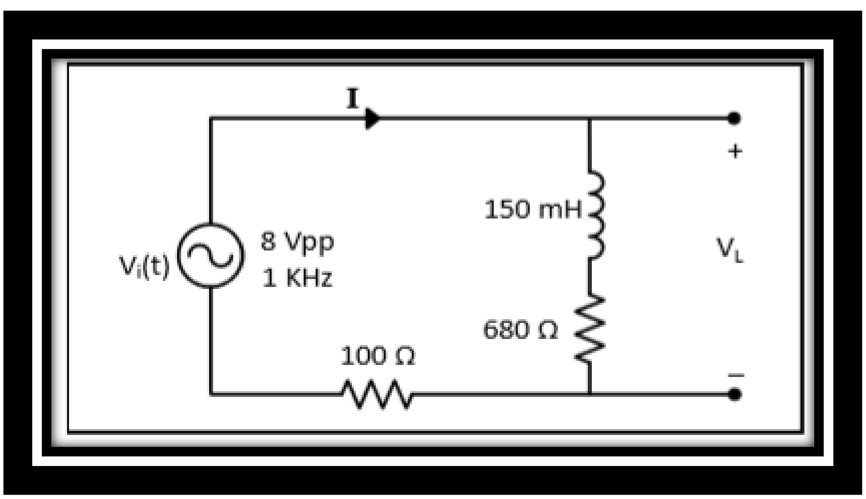

Figure 6

The oscilloscope was set to show the wave form of V_L and the wave form of voltage on the 100Ω resistor ,and by using time cursor ,the time difference between V_L and $V_{100\Omega}$ was measured and recorded in table3.

The RMS value of (V_L ,I) was measured using DMM and recorded in table 3

The value of ΔΘ was calculated and recorded in table3.

The value of power factor was calculated using the measured value ,and the real power and the reactive power consumed by the inductive load was calculated using measured value and recorded in table3

PART D: Power factor correction

The circuit in Figure7 was connected as the circuit in Figure 6 ,and capacitor was connected in parallel with the load

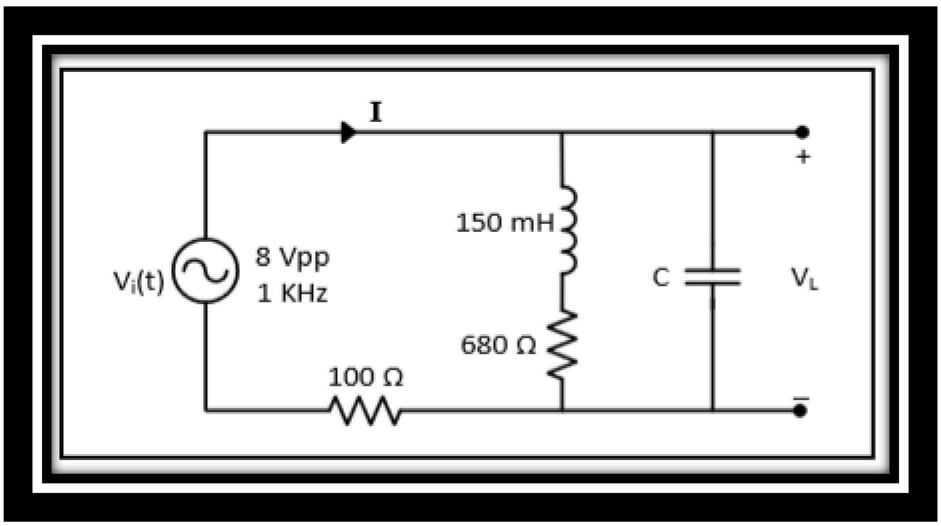

Figure 7

The value of added capacitor was calculated(in prelab) so that set the power factor to 1,The oscilloscope was set to show the wave form of V_{in} and the wave form of $V_{100\Omega}$,and by using time cursor ,the time difference between V_{in} and $V_{100\Omega}$ was measured and recorded in table4.

The RMS value of (V_L ,I) was measured using DMM and recorded in table 4

The value of ΔΘ was calculated and recorded in table4.

The value of power factor was calculated using measured value ,and the real power and the reactive power consumed by the inductive load was calculated using the measured value and recorded in table4

PART E: Maximum average power transfer

The circuit in the Figure 8 was connected ,and the impedance of the load was calculated in order to get the maximum power transfer to the load from the circuit

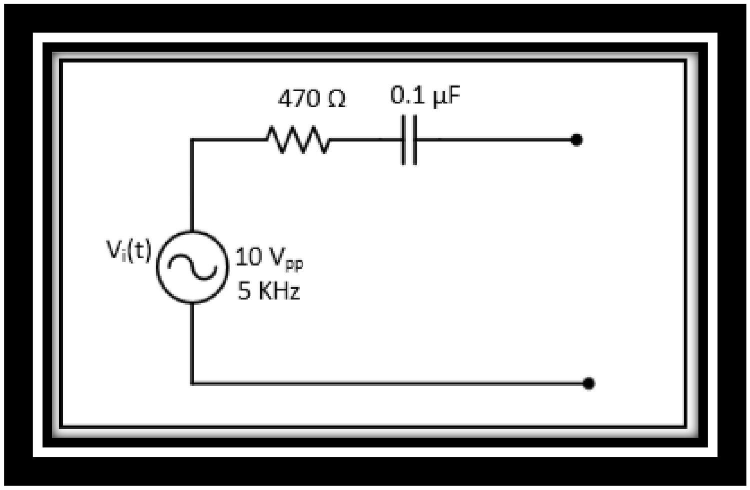

Figure 8

The RMS value of the current was measured by using DMM.

Data and calculation

Part A: DC power measurement

V_{in}[v]	0	2	4	6	8	10
I[mA]	0	1.8	3.9	6	7.96	9.9
P[mW]	0	3.6	15.6	36	63.6	99.5

Table1

From the table above, Noticed that as the value of input voltage increase the output power will increase also the value of current increase by increasing the input voltage (the relation between the current and voltage is linear).

The Figure below shows the relationship between the current and the power transferred in the load (the relation is quadratic)

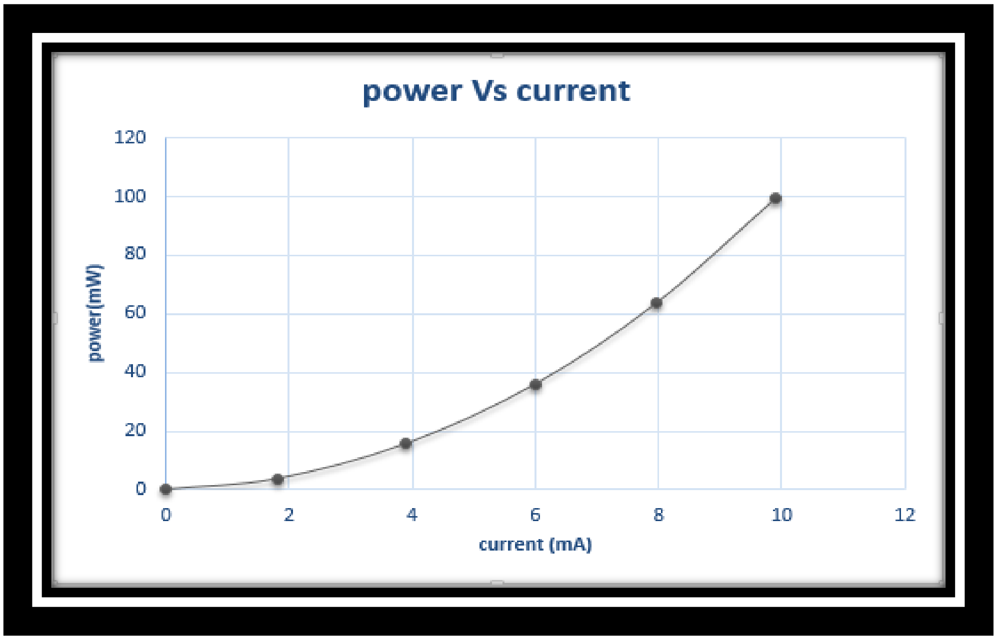

Figure 9

Part B: Maximum DC power transfer

RL	0	100	400	700	1k	1.1k	1.2k	1.3k	1.4k	1.5k	1.7k
I[mA]	3.46	3.6	2.65	2.21	1.75	1.68	1.63	1.57	1.51	1.45	1.35
P[mW]	0	0.69	2.3	3.1	3.5	3.47	3.47	3.45	3.43	3.39	3.31

Table2

R_{eq} = 1KΩ

From the table above, Noticed that as the value of load resistance increase the amount of power dissipated in the load increase until reach the specific value of R_L (R_L=R_{eq}) after that, any increasing in the value of the load resistance ,the power dissipated in the load will decrease .

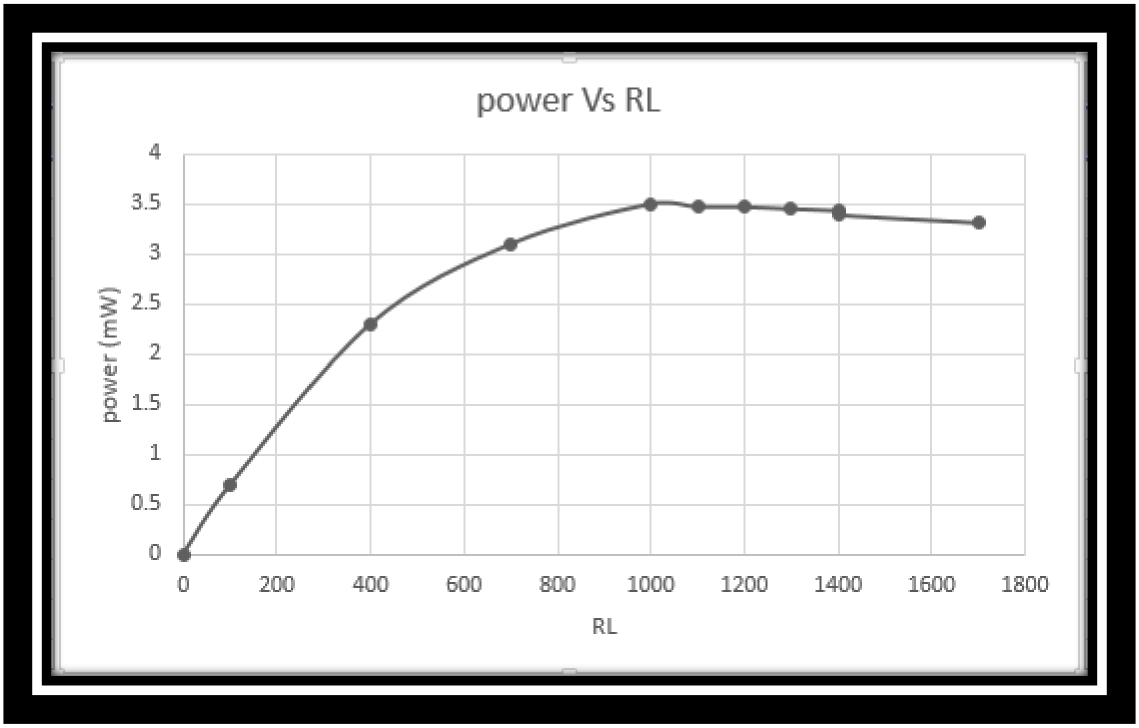

Figure 10

From the Figure above ,noticed that the maximum power transferred to the load when RL=1kΩ ,theoretically the value of R_{th} is 1.1 kΩ ,hence there was error

Error = $\frac{Rth-Rexp}{Rth}$ *100%= 9%.

Part C: Power factor measurement

Measure			**Calculate**			
V_L	**I**	**Δt**	**θ_L**	**PF**	**P[mW]**	**Q[mVAR]**
2.4	2.05	120μs	43°	0.72	3.76	3.5

Table 3

From the table above, the value of Δt was measured as shown below

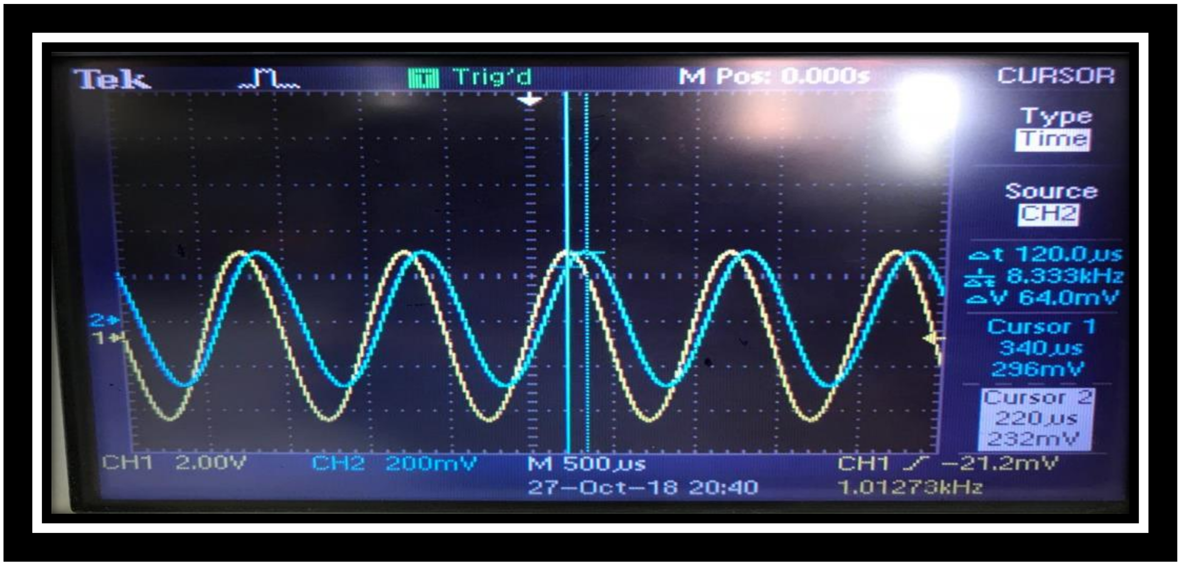

Figure 11

From the figure above, Noticed that there is time difference between the input voltage and the current ,and by using time cursor Δt = 120µs

ΔΘ = 360 * f * Δt = 43°

PF = cos(ΔΘ) = 0.72, the PF is lagging

Real power(P) = V_L * I *PF = 3.76 mW

Reactive power(Q) = V_L * I * sin(ΔΘ) = 3.5 mVAR

PART D: Power factor correction

Measure			**Calculate**			
V_L	**I**	**Δt**	**Θ_L**	**PF**	**P[mW]**	**Q[mVAR]**
2.4	1.9	0	0	1	4.56	0

Table 4

From the table above, the value of Δt was measured as shown below

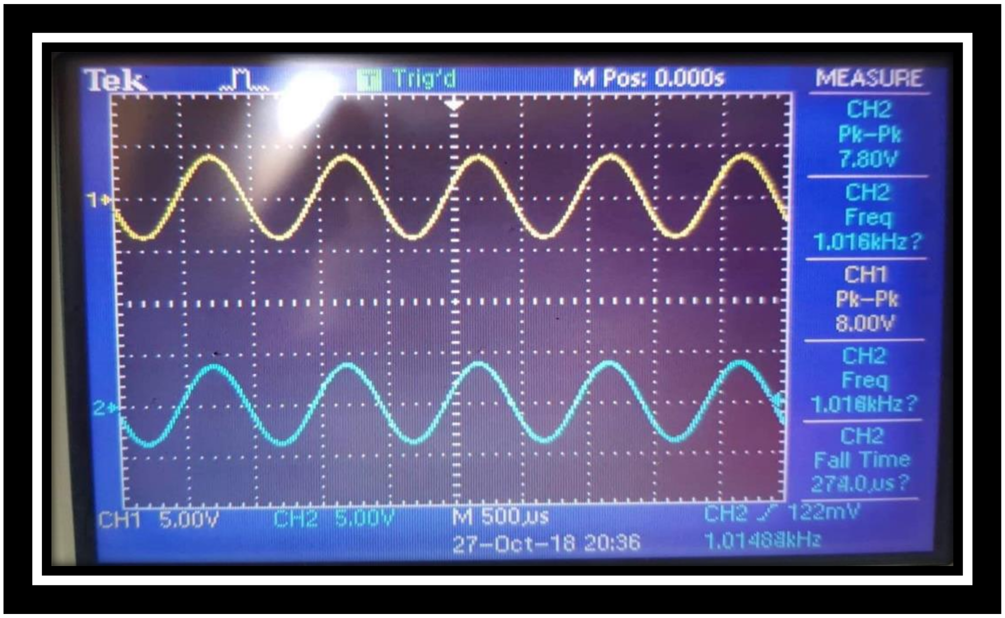

Figure 12

From the figure above, Noticed that there is no time difference between the input voltage and the current ,hence ,Δt = 0

$\Delta\Theta = 0^{\circ}$

PF = cos(ΔΘ) = 1

Real power(P) = V_L * I *PF = 4.56 mW

Reactive power(Q) = V_L * I * sin(ΔΘ) = 0 mVAR

As a result of adding capacitor ,the phase difference between the input voltage and the current was decreased to 0°,Hence , the power factor was increased to 1

PART E: Maximum average power transfer

when $Z_L = Z_{th}^*$, the maximum power will transfer to the load

$Z_{th} = 480 - \frac{1}{wc}$, $R_{th} = R_L$, $Z_L = 480 + wL$

$L = 1/w^2c = 10.1$ mH

I_L = 3.3 mA

maximum real power = $I_L^2 * R_L$ = 5.2 mW

conclusion

There are three kinds of power: active or real power, reactive power and apparent power. It is important to check for the value of the power factor; its value is close to one for better circuits, if not, some capacitors can be introduced to the circuit. For a Load to have maximum power transfer, its impedance has to equal the complex conjugate of Thevinen's impedance. However, we had some errors in our results due to the equipment used and also the impedances of cables used. nevertheless, we can say that our results are accepted as they are close to the true values, thus proving the theoretical part.

References

[1] circuit lab manual.

[2] Nillson & Riedel electric circuit 9th edition <chapter 10>.