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Finding Impedance and Power Factor from the Resonance Frequency- a New Innovative Way

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ABSTRACT: This paper proposed a new technique for finding impedance and power factor in a specific condition of Resonance Condition(RC) where supply is frequency variable so it is an important technique for variable supply frequency nearer of its resonance frequency. We all are known about the capacitive and inductive reactance which are directly depend upon the frequency so that we write the impedance equation and derive the equation with the help of binomial expansion and finally gets the result of impedance equation in a form of real and imaginary part by which we can calculate the impedance, power angle and power factor. When we found the impedance, power angle and power factor of a circuit at a certain frequency then we can construct the phasor diagram, can easily draw the wave diagram due to which can easily perform signal analyses, easy to understand sampling and also easily analysis the filter circuit in communication system and this technique also helps to analysis when frequency alter from the resonant frequency of the rectangular patch antenna then we can achieve resonance frequency unperturbed by placing perturbance below the patch about 30 percent decreases and 20 percent increases from the resonance frequency with maintaining size of rectangular patch antenna or array by not change its original size. About all are known about the net impedance of the RLC series circuit so I use the resonance terms i.e. fractional deviation, quality factor and resonance frequency etc. Now the equation becomes in the form of Fractional deviation and quality factor of RLC circuit in the form of complex term so we can easily find the require term and graph. In this technique, we can easily find the impedance by using this equation. Moreover, can also be calculate the power angle, power factor, complex term of frequency, wave and phasor diagram of the output signal of the RLC circuit at different frequency varying about resonance nearer to frequency so it is very useful technique.

KEYWORDS: Quality factor(Q), Resonance frequency(f0), Impedance(Z), Fractional Deviation(K)

I. INTRODUCTION

The property of cancellation of reactance when inductive and capacitive reactance are in series, or cancellation of susceptance when in parallel, has been known as resonance. It occurs at a certain frequency known as resonance frequency. [1] In this case, the parameters values change according to the modulation of the frequency. So, phasor values also change. According to frequency modulation there arises three cases. To construct phasor diagram, finding complex impedance, power factor, complex frequency, at resonance condition, we need complex resistance. If we find a complex resistance we can easily construct the phasor diagram. [2]

1) Less than resonance frequency
2) Equal to resonance frequency
3) Greater than resonance frequency

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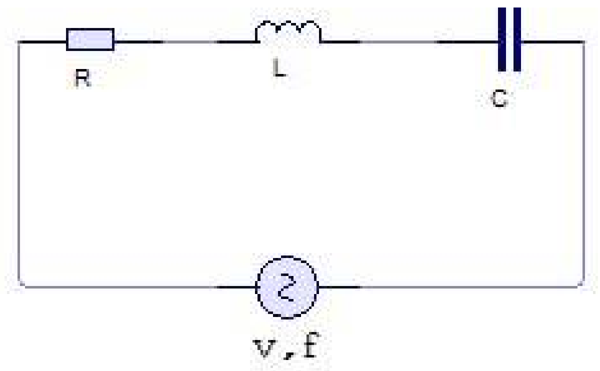
II. THEORY AND DERIVATION



1) Applied frequency are less than resonance frequency: -

The capacitive reactance term will exceed the inductive reactance and the circuit will appear as a capacitive reactance of value (1/**ω**.C) – **ω**.L in series with R. Where **ω** is angular frequency, L is inductance and C is capacitance.

The impedance Z of the circuit is [3]

$Z = R - j\,(\omega.L - \frac{1}{\omega.C})$

And near resonance the reactive term involves the calculation of the difference of two nearly equal numbers, so that the accuracy is difficult to obtain. A transformation allows this situation to be avoided.
Now the expression becomes,

$Z = R - j\sqrt{\frac{L}{C}}(\omega\sqrt{LC} - \frac{1}{\omega\sqrt{LC}})$

$= R - j\sqrt{\frac{L}{C}}(\frac{\omega}{\omega r} - \frac{\omega r}{\omega})$

Where ωr is defined as resonance frequency.

$\omega r = \frac{1}{\sqrt{LC}}$

Again, using this definition,

$Q = \frac{\omega r L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$

Where, Q is Quality factor.
And the impedance of the series circuit becomes

$Z = R\,[1 - j\frac{1}{R}\sqrt{\frac{L}{C}}\,(\frac{\omega}{\omega r} - \frac{\omega r}{\omega})\,]$

$= R\,[1 - j\,Q\,(\frac{\omega}{\omega r} - \frac{\omega r}{\omega})\,]$

A new variable '**k**' may be defined as

$K = \frac{f - fr}{fr} = \frac{\omega - \omega r}{\omega r}$

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Or $\frac{\omega}{\omega r} = 1 + \boldsymbol{k}$

It can be seen that **k** is the fractional deviation of the actual frequency from the resonant frequency. If **k** is introduced into above impedance equation, then

Z = R [1 – j Q (1+ **k** – $\frac{1}{1+k}$)]

The binomial theorem may be used to expanding

$$1 / (1 + \boldsymbol{k})^1 \; giving$$

$$(1 + \boldsymbol{k})^{-1} \cong 1 - \boldsymbol{k} + \boldsymbol{k}^2 + \ldots..$$

Neglecting higher powers of **k**, since **k** is always small with respect to unity. Then

$$Z = R\,[1 - j\,Q\,\mathbf{k}\,(2 - \mathbf{k})]$$

The above expression of the impedance of the series resonant circuit for small deviation from the resonant frequency is in a form well suited to computation.

2) Applied frequency equal to resonance frequency: -

In this condition, the reactive part of the circuit is completely removed due to inverse phase characteristics of inductive and capacitive reactance.

So, the complex impedance becomes

Z = R +j0

3) Applied frequency are less than resonance frequency: -

The capacitive reactance term will less than the inductive reactance and the circuit will appear as an inductive reactance of value **ω**.L **-** (1/ **ω**.C) in series with R. Where **ω** is angular frequency, L is inductance and C is capacitance.

The impedance Z of the circuit is

$Z = R + j\,(\omega.L - \frac{1}{\omega.C})$

And near resonance the reactive term involves the calculation of the difference of two nearly equal numbers, so that the accuracy is difficult to obtain. A transformation allows this situation to be avoided.

Now the expression becomes,

$Z = R + j\sqrt{\frac{L}{C}}(\omega\sqrt{LC} - \frac{1}{\omega\sqrt{LC}})$

$= R + j\sqrt{\frac{L}{C}}(\frac{\omega}{\omega r} - \frac{\omega r}{\omega})$

Where **ω**r is defined as resonance frequency.

$\omega r = \frac{1}{\sqrt{LC}}$

Again, using this definition,

$Q = \frac{\omega r L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$

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Where, Q is Quality factor.
And the impedance of the series circuit becomes

$Z = R\,[1 + j\,\frac{1}{R}\sqrt{\frac{L}{C}}\,(\frac{\omega}{\omega r} - \frac{\omega r}{\omega})\,]$

$= R\,[1 + j\,Q\,(\frac{\omega}{\omega r} - \frac{\omega r}{\omega})\,]$

A new variable '**k**' may be defined as

$K = \frac{f - fr}{fr} = \frac{\omega - \omega r}{\omega r}$

Or $\frac{\omega}{\omega r} = 1 + \boldsymbol{k}$

It can be seen that **k** is the fractional deviation of the actual frequency from the resonant frequency. If **k** is introduced into above impedance equation, then

$Z = R\,[1 + j\,Q\,(1 + \mathbf{k} - \frac{1}{1+\boldsymbol{k}})\,]$

The binomial theorem may be used to expanding

$$1 / (1 + \boldsymbol{k})^1 \ giving$$

$$(1 + \boldsymbol{k})^{-1} \cong 1 - \boldsymbol{k} + \boldsymbol{k}^2 + \ldots..$$

Neglecting higher powers of **k**, since **k** is always small with respect to unity. Then

$$Z = R\,[1 + j\,Q\,\mathbf{k}\,(2 - \mathbf{k})]$$

The above expression of the impedance of the series resonant circuit for small deviation from the resonant frequency is in a form well suited to computation.

III. RESULT

From above derivation we found the impedance, power angle and power factor of a circuit at a certain frequency then we can construct the phasor diagram, can easily draw the wave diagram due to which can easily perform signal analyses, easy to understand sampling and also easily analysis the filter circuit in communication system.

IV. CONCLUSION

In this technique, we can easily find the impedance by using the above equations. Moreover, can also be calculate the power factor, complex term of frequency, wave with phasor diagram of the output signal of the RLC circuit at different frequency varying about resonance nearer to frequency so it is very useful technique so this technique also helps to analysis when frequency alter from the resonant frequency of the rectangular patch antenna then we can achieve resonance frequency unperturbed by placing perturbance below the patch about 30 percent decreases and 20 percent increases from the resonance frequency with maintaining size of rectangular patch antenna or array by not change its original size [4].

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