A study of electrical Tank Circuit and its limitations

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ABSTRACT *Parallel resonance circuits of RLC can be treated as a source of current and frequency to some extent, wherecapacitance and inductance play a vital rolewhile using A.C source and some unusual achievements occur due to parallel connection of capacitance and inductance, though resistance (very small) is also connected in series either with inductance or capacitance.At resonant, the parallel circuit current is the minimum and quality factor of their parallel combination is usually high, so capacitor current as well as inductor current is much higher than the source current i.e. current magnification takes place. Capacitor and inductor not only make current magnification but in addition to that desirable resonance frequency can be obtained by changing capacitance or inductance or both, offering the highest value of impedance at that frequency.The practical behaviour of the circuit seems to be a reservoir of the frequency as well as a reservoir of current simultaneouslyand energy store in the form of magnetic energy in inductorand in the form of electrical energy in capacitor.*

Keywords: *Resonant frequency, capacitor current, inductor current, current magnification.*

I Introduction: Parallel resonance circuit is formed either resistance(R) and inductance (L), first connected in series and this combination is connected with capacitance (C) in parallel or first resistance(R) and capacitance (C) are connected in series and the series is connected with inductance (L) in parallel, but the earlier way is usually used for drive. When parallel combination is connected with source voltage, current starts flowing through the combination and as inductance and capacitance are always connected in parallel, inductor current and capacitor current will be 180^0 out of phase, for small series resistance. Capacitor current leads by an angle 90^0 with the source voltage and inductor current lags the same angle with source voltage. At resonant, quality factor of the parallel combination is usually high and it depends on resonance frequency, inductance and the resistance, and capacitor current as well as inductor current both are much higher than the source current i.e. current magnification takes place and resonancefrequency also related with inductor, capacitor and the resistance which is usually connected with inductance in series. But to achieve the goal, i.e. to have sharp resonance curve, series resistance should be small; hence resonance frequency exclusively depends on capacitor and inductor. Desirable resonance frequency can be achieved by changing capacitor or inductor or both simultaneously and at that time, resulting a maximum impedance and impedance, admittance of the circuit depends on the three parameters. So the RLC parallel circuit provides as a source of frequency and on the other way the current of the each combination higher than the source current at resonance, the circuit can be treated as the reservoir of current, hence for both the reasons RLC parallel circuit may be called reservoir or tank circuit. For smaller value of series resistance capacity/range of frequency or current reservoir depends on inductance and capacitance. So for tank circuit, the values of capacitance and inductance are very important.

II Theory and calculation

For the formation of tank circuits with respect to current and frequency, RLC parallel resonant circuit can be used in both ways as shown in fig: 1 and fig: 2. In fig: 1; series combination of R and L are connected in parallel with C and this combination connected with A.C source, whereas in fig: 2, R and C are connected first in series than it is connected with L in parallel, finally this whole combination connected with source.

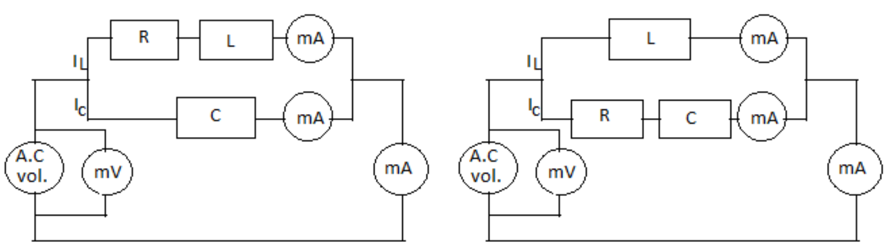

Fig.1 Fig.2

For the present work circuit connection are used as shown in fig: 1. In the circuit, three digital milli- ammetre (mA) are used simultaneously, one is connected with the series combination of R and L to measure the inductor current, next one is connected with capacitor for the measurement of capacitor current and the last one is used with the parallel combination of RL and C to measure the circuit current. Inaddition to that, digital volt metre is connected with the source. The range of the voltmeter is from 0.00 volt to 12.00 volts and that of for milli-ammetres (mA) from 0.00 mA to 20.00 mA. Digital A.C source's frequency (frequency generator) can be controlled from single digit to thousands (in Hertz) in the experiment.

From fig: 1, total current of the circuit, $I = I_L + I_C$ where I_L is the inductor current which flows through the series combination of R and L and I_C is the capacitor current flows through the capacitor only.

And, $I_L = E_0 e^{jwt} /(R + jwL), I_C = jwC(E_0 e^{jwt})$ -----[1]

$I = E_0[e^{jwt} /(R + jwL) + jwCe^{jwt}]$ ------- [2]

If Z is the impedance of the circuit, $Z^{-1} = [R + j(w^3L^2C + wCR^2 - wL)]/[R^2 + w^2L^2]$ ---- [3]

At resonance the circuit and source voltage are in the same phase, so imaginary part of the denominator of the expression of impedance is zero, which provides the parallel resonance frequency (in Hertz)

$f_r = [1/LC - R^2/L^2]^{0.5}/2\pi$ ----- [4]

According to the equations [1] and [2], it is obvious that total current, induction current and also capacitor current change with the change of source frequency for fixed values of R, L and C. It is also true about the dependency of currents on R, Land C when frequency is fixed. For fixed values of circuit components, combined impedance increases with the increase of frequency from the lower values of frequency and at that time the role of inductance is higher compared to the role of capacitance. So circuit current decreases with the increase of frequency, and fora particular frequency the circuit impedance is the maximum and the corresponding circuit current is the minimum though the capacitor and inductor currents are much higher than the value atany other frequencies. This particular value of frequency is the resonant frequency of the parallel RLC circuit and it is only possible when circuit current and applied source frequency are in the same phase. The various currents can be measured directly with the digital meters and also the different frequencies including resonant frequency, can be noted down with. Resonant frequency also can be checked by knowing the numerical values of circuit components using the equation [4]. To connect the instruments and circuit parameters, copper straight wires having minimum lengths were used.

III Results

Throughout the experiment the input voltage keeps constant. The resistance connected with inductance should be small and in the work constant value of R is used (100ohms).From the equations [1] and [2], and at laboratory it is experimentally observed the variation of total current, inductor current and the capacitor current of the circuit with frequency and minimum current of the circuit is found at a particular frequency forfixed set of R, L and C, i.e.resonant currentand corresponding resonant frequency are recorded. To achieve the final value of minimum current adjustments of frequency have done several times and mean value recorded. At that time inductor current as well as capacitor current are also noted down. The mean values of resonant frequency, resonant current, inductor current and capacitorcurrent from several observations and fixed set of components are treated as the final results of these parameters. In the present study at first different capacitors are used for fixed values of R and L. Nine different capacitors from 0.10 μF to 5.0 μF are used and one by one 10 different inductorshaving values 8.18 mH to 60.0 mH are connected in the circuit.The mean values of resonant frequency, resonant current, inductor current and capacitor current for different sets are recorded shown in the tables. From the recorded data it is observed that for a particular inductance resonant frequency decreases with the increase of capacitance, whereas resonance current and inductor current increases with the increase of capacitance i.e. when total current of the circuit is the minimum, inductor and capacitor both currents are maximum but all these currents are in mA in order. For the measurement of capacitor current, sometimes the value crossed the range of the instrument, but it is always increases with the increase of capacitor sometimes these are greater thanthe tabulated data. For some capacitors, resonant frequency and resonance current etc. could not measure with instruments used in the present experiment. For a particular capacitor, resonantfrequency decreases with the increase of inductance.Inductor current and capacitor current also increase with the increase of inductance for a fixed resistance and capacitance. Symmetric changed in resonant frequency, resonant current, inductor current and capacitor current with L and C are not observed due to discrete and as-symmetric values of L and C used in the present case.

L= 8.18mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF
Resonant frequency (f_0) in Hz.	3716	2224	1672	1047	869	430	89	---	---
Circuit current(I) at resonant frequency in mA	0.71	1.04	1.27	2.39	2.23	3.21	---	---	---
Inductance current(I_L) at resonant in mA	4.92	5.33	5.54	3.84	6.03	5.11	---	---	---
Capacitor current(I_C) at resonant in mA	10.56	10.56	10.59	10.56	10.58	10.58	---	---	---
L=10.0mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF
Resonant frequency (f_0) in Hz.	2914	1863	1244	996	593	323	214	153	135
Circuit current(I) at resonant frequency in mA	0.71	1.04	1.24	1.82	2.29	3.37	3.53	3.86	3.88
Inductance current(I_L) at resonant in mA	4.79	5.14	5.04	4.07	6.26	6.01	5.82	5.69	5.71
Capacitor current (I_C) at resonant in mA	11.29	11.28	11.26	11.22	13.48	13.53	13.54	13.54	13.64
L=11.0mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF
Resonant frequency (f_0) in Hz.	4372	2475	1817	1070	780	391	307	287	---
Circuit current(I) at resonant frequency in mA	1..19	1.75	1.91	2.56	2.82	3.46	3.08	3.81	---
Inductance current(I_L) at resonant in mA	6.97	7.17	7.38	5.04	6.90	6.47	7.24	9.70	---

Capacitor current(I_C) at resonant in mA	15.68	15.68	15.78	15.78	15.49	14.68	15.13	14.19	---
L=16.31.0mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF
Resonant frequency (f_0) in Hz.	3735	2163	1694	1047	816	530	286	356	---
Circuit current(I)at resonant frequency in mA	0.72	1.05	1.28	2.41	2.19	3.33	3.64	4.5	---
Inductance current(I_L) at resonant in mA	4.91	5.31	5.62	3.86	5.81	5.66	7.02	6.00	---
Capacitor current(I_C) at resonant in mA	10.62	10.64	10.64	10.65	10.65	10.65	10.63	--	---

L= 23.0 mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF
Resonant frequency (f_0) in Hz.	3082	1756	1320	1061	641	324	215	---	---
Circuit current (I)at resonant frequency in mA	0.76	1.1	1.31	1.85	2.07	2.89	3.66	---	---
Inductance current(I_L) at resonant in mA	4.86	5.02	5.11	4.06	5.31	4.95	5.55	---	---
Capacitor current(I_C) at resonant in mA	11.30	11.30	11.29	11.22	11.22	11.26	12.87	---	---
L=25.0mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF
Res0nant frequency (f_0) in Hz.	2988	1732	1252	1041	563	324	232	154	----
Circuit current (I)at res0nant frequency in mA	0.71	1.03	1.24	1.78	2.01	2.75	2.84	3.14	---
Inductance current(I_L) at res0nant in mA	4.83	5.04	5.06	4.08	5.07	5.02	4.97	4.7	---
Capacitor current (I_C)at resonant in mA	11.28	11.28	11.28	11.26	11.24	11.28	11.26	11.20	---
L=25.6 mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF

Resonant frequency (f_0) in Hz.	3241	2119	1679	---	944	549	329	---	---
Circuit current(I) at resonant frequency in mA	0.25	0.57	0.84	---	1.98	3.24	3.66	---	---
Inductance current(I_L) at resonant in mA	7.88	8.35	8.44	---	8.44	6.60	5.48	---	---
Capacitor current(I_C) at resonant in mA	11.28	10.50	11.09	---	11.25	11.18	11.26	---	---
L= 40.0 mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF
Resonant frequency (f_0) in Hz.	2812	1733	1300	1050	697	411	228	---	---
Circuit current(I) at resonant frequency in mA	0.55	0.85	1.06	1.79	1.83	2.56	3.06	---	---
Inductance current (I_L)at resonant in mA	4.99	5.33	5.42	4.09	5.91	5.54	4.92	---	---
Capacitor current (I_C)at resonant in mA	11.29	11.32	11.31	11.28	11.28	11.27	11.26	---	---

L=48.4 mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF
Resonant frequency (f_0) in Hz.	2284	1526	1255	1051	738	493	337	443	---
Circuit current (I)at resonant frequency in mA	0.15	0.35	0.52	0.66	1.33	2.66	3.06	2.33	---
Inductance current (I_L)at resonant in mA	6.92	7.36	7.45	4.07	7.69	6.3	6.14	6.7	---
Capacitor current (I_C)at resonant in mA	11.26	10.25	11.23	11.21	11.25	11.26	11.22	---	---
L=60.0mH R=100 ohms V_i= 0.55volts.									
	C=0.1 μF	C=0.22 μF	C=0.33 μF	C=0.47 μF	C=1.0 μF	C=2.0 μF	C=3.0 μF	C=4.0 μF	C=5.0 μF
Resonant frequency (f_0) in Hz.	2162	1393	1122	---	585	345	219	183	---

Circuit current(I) at resonant frequency in mA	0.41	0.63	0.80	---	1.45	2.16	2.53	2.93	---
Inductance current (I_L)at resonant in mA	4.8	5.15	5.37	---	5.76	5.53	5.07	5.13	---
Capacitor current(I_C) at resonant in mA	11.05	11.25	11.22	---	11.27	11.27	11.28	11.29	---

IV Discussions and conclusion

It is found from the table that resonant frequency can be varied either by changing L (inductor), keeping C (capacitor) is constant or by changing C when L remains the same. And also resonantfrequency may be altered by varying L and C simultaneously. For fixed value of L, resonant frequency decreases with the increase of C when all other parameters like R and input voltage etc. remains constant. In case of constant value of C, it is almost inversely proportional to inductance. Above all a large range of resonant frequency can be achieved due to different values of L and C. So it may be concluded that the parallel resonant circuit can be considered as a source of frequency or frequency tank (supplier). Another interesting point also noted down from the table that inductor current and capacitorcurrent both are very large compared to resonant current (input source current). At that time inductor and capacitor currents both are Q (quality factor of parallel resonant circuit)times of the supplied current and these current depends on the values of inductor and capacitor. Hence the parallel resonant circuit can be also be treated as the source of various values of current which depends on the values of L and C, so the circuit can be renamed as tank of current. Finally altogether parallel resonant circuit is the source of frequency and current simultaneously and the various values of obtained frequency and current actually depend on capacitance as well as on inductance, though there is a limit of the capacity of the tank. Therefore for the tank circuits, the range of current source or frequency source are depends on the values of L and C.

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