Power Divider Rule: AC circuit analysis

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Abstract

The revolution of electricity formulation was started in early 17th century and superficially ended up with the electrical current divider as well as the voltage divider rules. As a matter of fact, the product of these two components (current and voltage) is the electrical power and this approach has been conventionally applied for any circuits' calculation so far. The power divider rule (PDR) is an alternative mathematical formula for the computation of electrical power distribution across any DC electrical circuits and it was published in the Electronics World - UK magazine, a 150 years old periodic. The mathematical analysis was limited to only the DC circuits and therefore an extended analysis becomes crucial to implicate the formula into practical application today, especially in the AC circuit calculations. To what extend the power divider rule works well in AC circuit is still an ambiguity as there is short of literature on it since the day of publication. Literally there is no substantial analysis has been done yet to produce pertinent results and thereby, the power distribution in AC circuits are thoroughly investigated in this paper. The ideal and non-ideal simulating results show an authenticity of the formula because it works well in the AC circuits in addition to the DC circuits.

Keywords: Power Divider Rule, Power Dividing Technique, Power Conservation

Introduction

Analyzing the electrical circuit is a conventional practice in electrical engineering and today, the current divider rule and voltage divider rule are predominantly solve the complicity of electrical circuits' theories. Instead of using the current divider rule and voltage divide rule always, a new formulation is considered from an ISI journal (Electronics World-UK) and then analyzed in electrical circuit making software (Circuit Maker Pro-2000) for the authenticity. The formula was named as power divider rule (PDR), which computes the power sharing in any electrical DC circuits. It implies that: "The total dissipated power is equal to the total supplied power regardless of circuit configuration". The publication has been shown in **Error! Reference source not found.** as a courtesy of Electronics World – UK magazine[1]. In this paper, the analysis is extended to AC circuit simulation [2, 3, 4, 5].

Analytical Concept

Electrical circuit making software

Circuit Maker™ 2000 is the most powerful, easy-to-use schematic capture and simulation tool in its class, having the features of "high-end" design software at a fraction of the cost[6, 7, 8]. It is used to draw, edit, test, and simulate electronic circuits (figure 1).
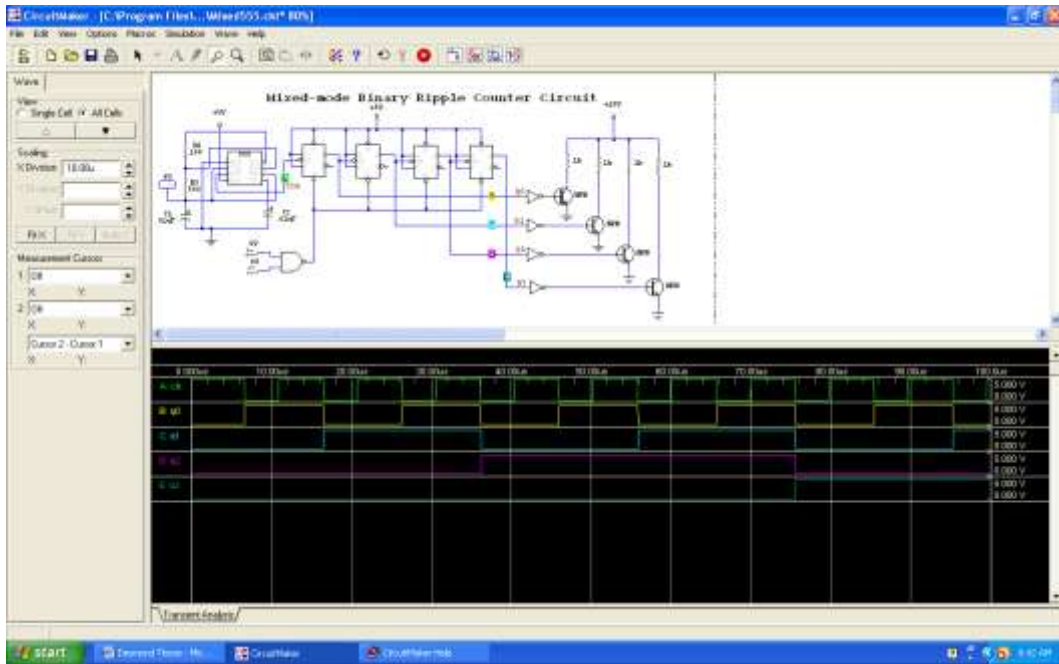
Figure 1: Circuit Maker Pro 2000 (Overall outlook)

Using its advanced schematic capabilities, the designing aspects cover electronic circuits' simulation, output netlists for Trax Maker and other PCB design tools. It enabled to perform fast, accurate simulations of digital, analog and mixed analog/digital circuits, just in a laptop for the sake of simplicity[9, 10].

Software setups

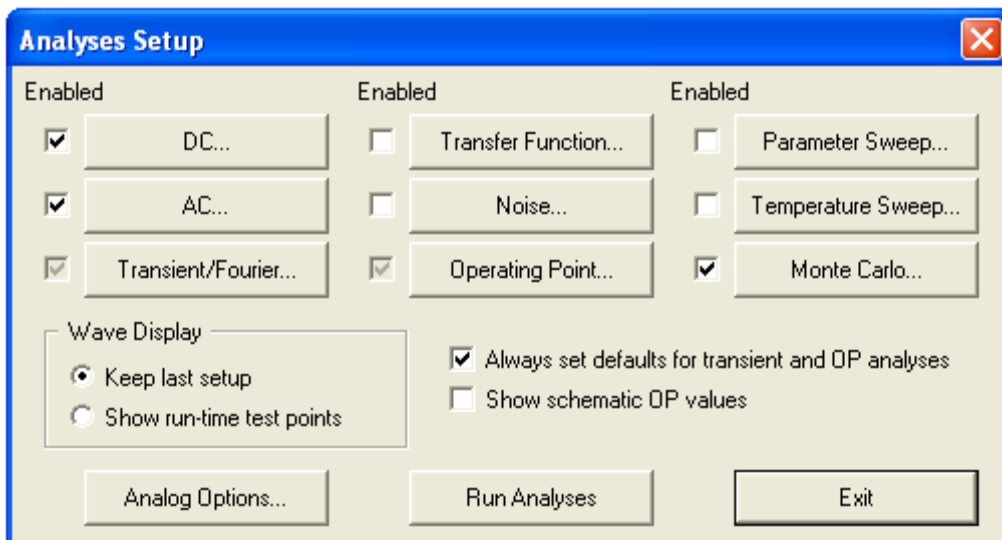The software was tuned to run the DC and AC simulations as well as the monte-carlo analysis, exclusively.

Figure 2: Circuit Maker's analyses setup

This internal set up has helped to run simulation for more than ten times, just once (figure 2). With such an arrangement, the entire analysis has been carried out to obtain sufficient and appropriate results to characterize

the authenticity of power divider rule.

Electrical circuits' configuration

Two types of electrical circuits are finalized to carry out the simulative investigation. Firstly, the series circuit (figure 3.a) for which the amount of electric current remains the same but voltage varies in the branches of configuration. Secondly the parallel circuit (figure 3.b) for which the amount of electric current varies but voltage remains the same in the branches of configuration. In advance analysis, more than two branches of circuit's configuration are established[11].
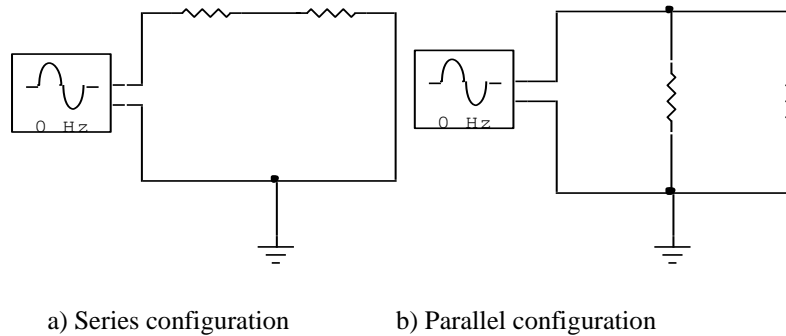

a) Series configuration   b) Parallel configuration

Figure 3: Circuit configurations

Electrical circuits' parametric setups

In order to carry out the AC simulation, the signal generators' voltage levels are assigned to be ± 10 VAC with 50 Hz constant frequency. Ground source is the reference point and is being used in the standard form without any adjustment. However, the resistor, inductor and capacitor values are randomly varied as to see the effects in terms of waveforms. The values for resistors have been widely varied from 10 to 10 MΩ; meanwhile the inductors values have been varied from 10 to 10 µH. Likewise, the capacitor values have been varied from 10 to 100 nF.

Results and Discussion

Conventional rules in electrical engineering

In electrical engineering, the Ohm's law (eq.

1) is the fundamental formula to computer the relationship between the resistance, current and voltage (figure 4). Thus, the product of resistance and current is the voltage. Moreover there are other useful formulas available to compute the branch current and voltage; such as the current divider (eq. 5, 6) and voltage divider (eq. 3, 4) rules. All of these formulas are equally obeying and adhering the fundamental principles. However, the amount of power is calculated from different formula, Power, $P = VI$ (eq. 2); which can again be said that the product of voltage and current [12, 13, 14, 15].
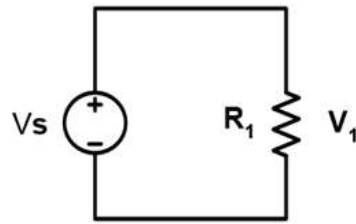
$$V = IR \qquad \text{Equation 1}$$

$$P = VI \qquad \text{Equation 2}$$

Figure 4: Simple electrical circuit (I = Current, R = Resistance, V = Voltage and P = Power)

Voltage divider rule is implied that any branch voltage can be calculated by multiplying the respective resistor with supply voltage over sum of total resistance (figure 5). This can be easily expounded by using mathematical notation given below (eq. 3, 4)[16].
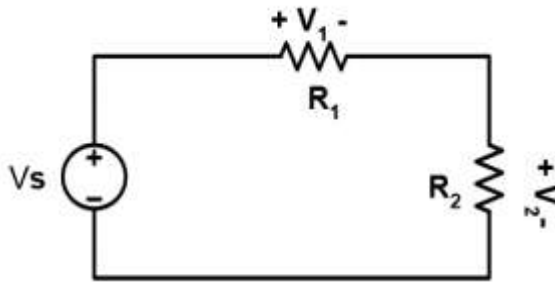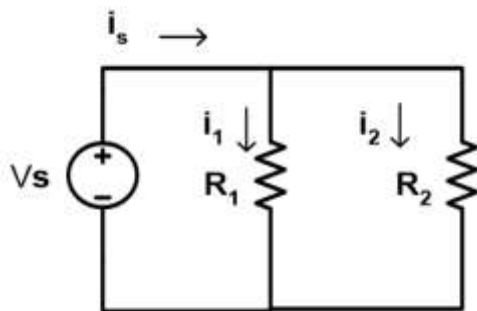
$$V_1 = \frac{R_1}{R_1 + R_2} V_s \qquad \text{Equation 3}$$

$$V_2 = \frac{R_2}{R_1 + R_2} V_s \qquad \text{Equation 4}$$

Figure 5: Voltage is shared by two resistors

Similarly the current divider rule (figure 6) is expounded by using mathematical notation given in equation 5 and 6.

$$i_1 = \frac{R_2}{R_1 + R_2} i_s \qquad \text{Equation 5}$$

$$i_2 = \frac{R_1}{R_1 + R_2} i_s \qquad \text{Equation 6}$$

Figure 6: Current is flowed into two branches

Newly published rule (The power divider rule)

The newly-published formula is stating that: "the total dissipated power is equal to the total supplied power regardless of circuit configuration"[1]. Hence the power source is now drawn for two circuits configuration and shown below with mathematical formula, accordingly.
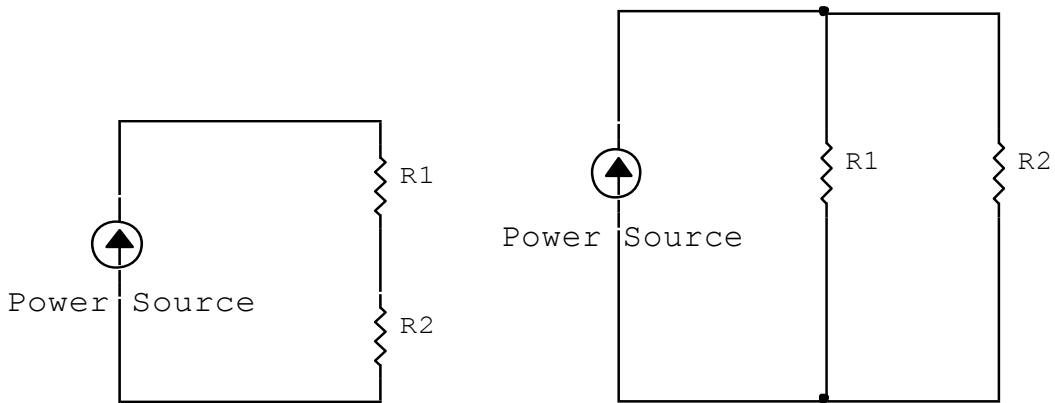

Figure 7: Power dividing methodology regardless of circuit configuration

The power divider rule is an identical in term of arrangement to voltage divider rule and is summarized below as equation 7 and 8.

$$P_1 = \frac{R_1}{R_1 + R_2} P_s$$ Equation 7

$$P_2 = \frac{R_2}{R_1 + R_2} P_s$$ Equation 8

AC Circuit Simulation

      Core analysis of the entire investigation is starting from here on; as the first circuit is the RL circuit (figure 8), having connected with a sinusoidal source (AC supply). The input signals will be kept constant throughout the entire simulations but the values of resistor (R), inductor (L) and capacitor (C) will be varied[17]. The selected values for components are shown on the top of components in electric circuits and resistor is marked by 'A', inductor is marked by 'B' and capacitor is marked by

'C'. By doing so, a random selection will occur as to verify the power dividing rules for AC sources. Result shows that the resistor has positive power accumulation while the inductor has sinusoidal effect, paving ways for the charging and discharging effects; electro-magnetically. Since the scope is to analyze the power divider rule, the focus has been brought down to wave form comparison. So from figure 40, which represents the LC- series circuit stimulus that the total dissipated power at resistor and inductor is equal to the total supplied power. The power at

resistor does not have any negative portion but the inductor has[18]. The power at inductor fluctuates for positive and negative portions due to its nature (electro-magnetically coupled principles). The dissipated power at resistor is marked by 'A'. It is 99.86 mille Watt for maximum and the minimum is 43.90 micro Watt approximately. Whereas the dissipated power at inductor is marked by 'B'; which has a maximum value of +15.67 nano Watt and a

minimum values of -15.08 nano Watt approximately. So the addition of both, A and B is the total supplied power. In this analysis, the total supplied power is; the maximum as +99.66 mille Watt and the minimum is 613.99 micro Watts approximately (figure 9). The approximation seems to be effective in this analysis as the circuit maker computers for ideal case at this stage.
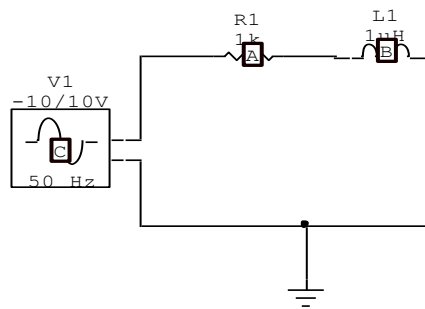

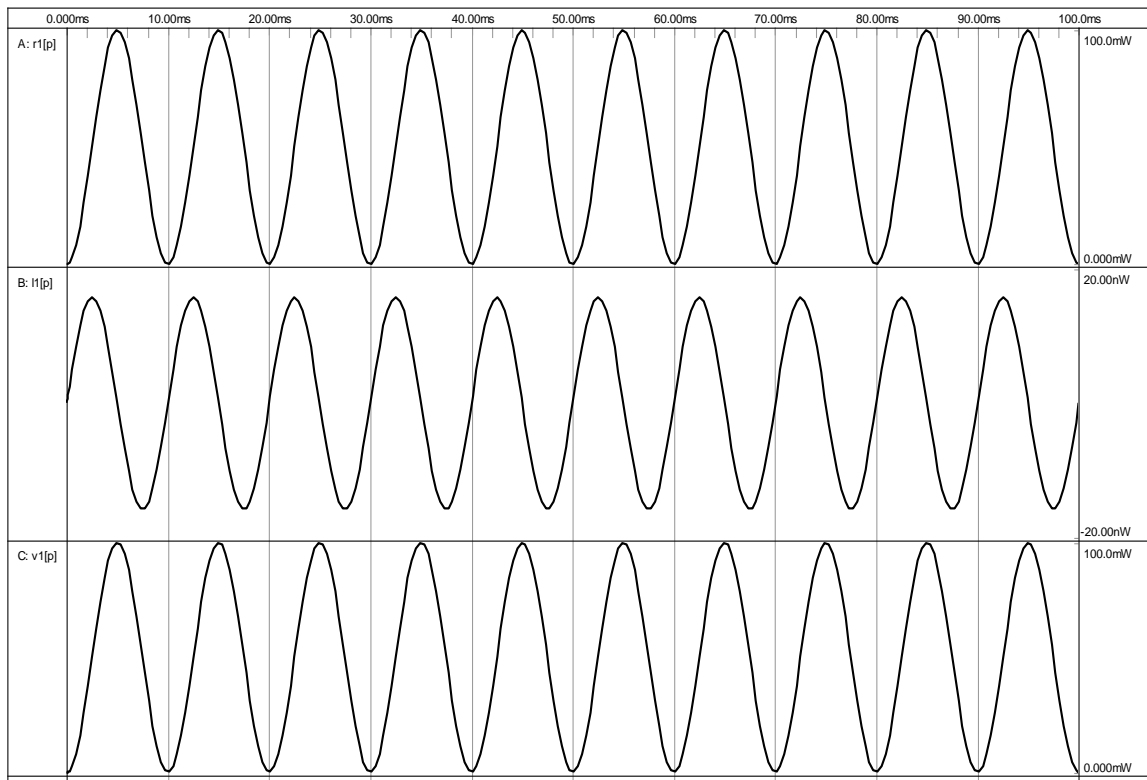Figure 8: Schematic diagram for the RL series circuit

Figure 9: Waveforms of the RL series circuit

The second test is about the RC combination in series circuit. Figure 8 shows such an arrangement with a value of 1k ohm resistor in series connection with a 1 micro Farad capacitor. When this circuit is supplied with ± 10 VAC, then the corresponding results are shown in figure 42. Value at resistor, the point marked by 'A' is 8.97 mille Watt max. and 13.97 micro Watt min. As for the capacitor, the point marked by 'B' is max. 14.27 mille Watt and min. 14.17 mille Watt. With the addition of A and B in accordance with PDR, the corresponding waveform 'C' shows (figure 10) a value of max. 19.43 mille Watt and min. -10.37 mille Watts.
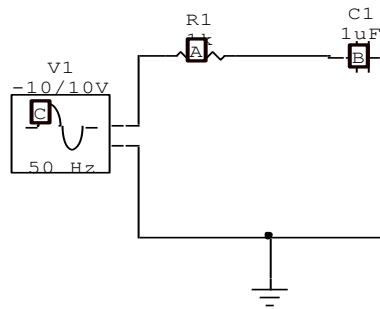

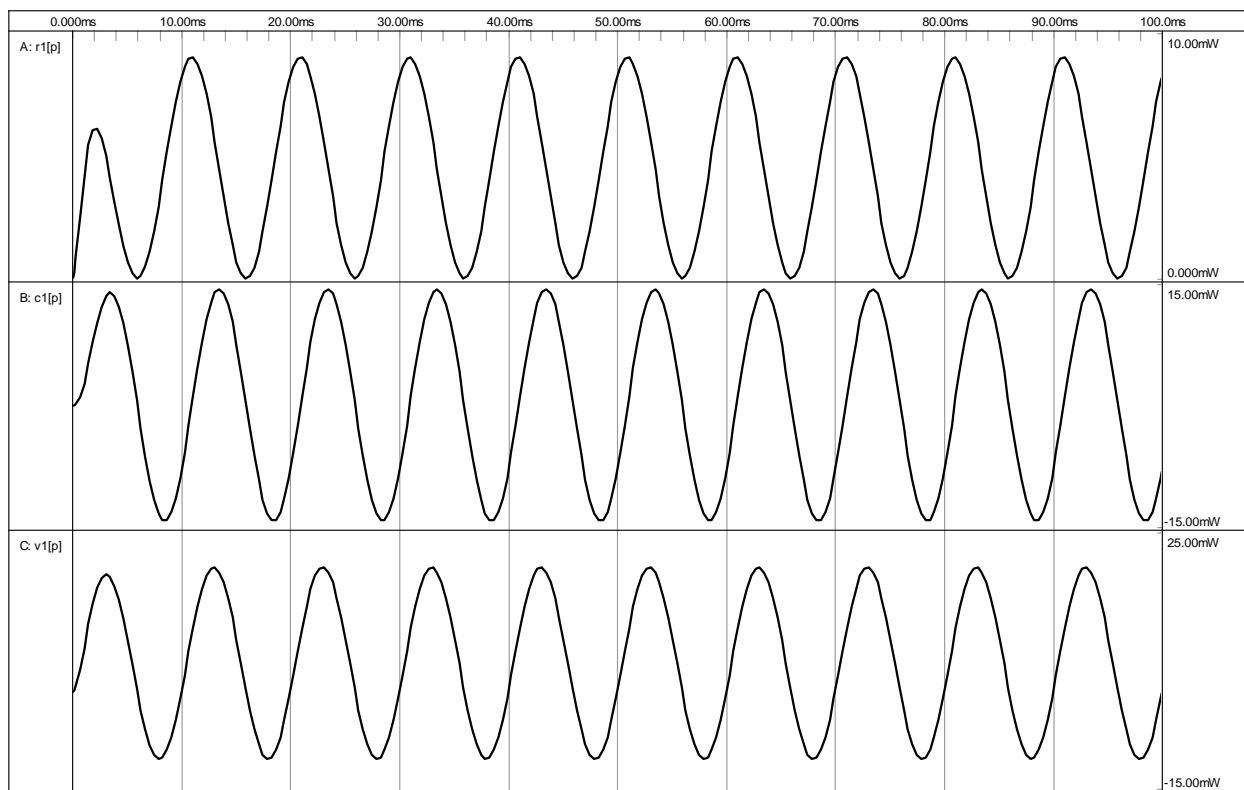Figure 10: Schematic diagram for the RC series circuit

Figure 11: Waveforms of the RC series circuit

In third attempt, the RL combination is connected in parallel and subsequently tested for the outcomes (figure 11). Immediately notice that it has given the tank circuit effects, from which a damping oscillation

is released[18, 19]. As to check the PDR concept indeed, a diode has been connected in between the resistor and inductor to prevent the damping oscillation. Connecting a diode was very successful in this case as the damping oscillation is completely removed. With the aid of a diode, final simulation is carried out. Figure 12 shows the corresponding results for the RL circuit in parallel. Point 'A' has

99.87 mille Watt as maximum and 427.2 mille Watt as minimum whereas the point 'B' has 306.83 kilo Watt as max. and -335.84 kilo Watt as min. Of course the supplying power must tally the sum of A and B to prove the PDR; and in this case, the point 'C' has 351.31 kilo Watt as max. and -294.6 kilo Watt as min. The entire wave pattern with diode interconnected is shown in figure 13.
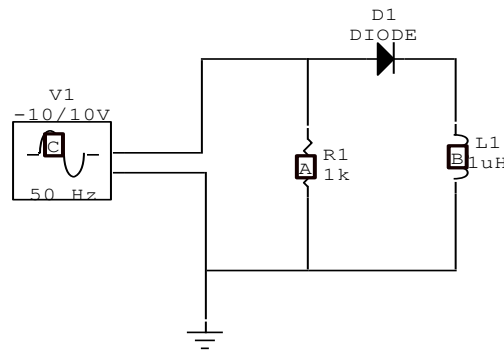

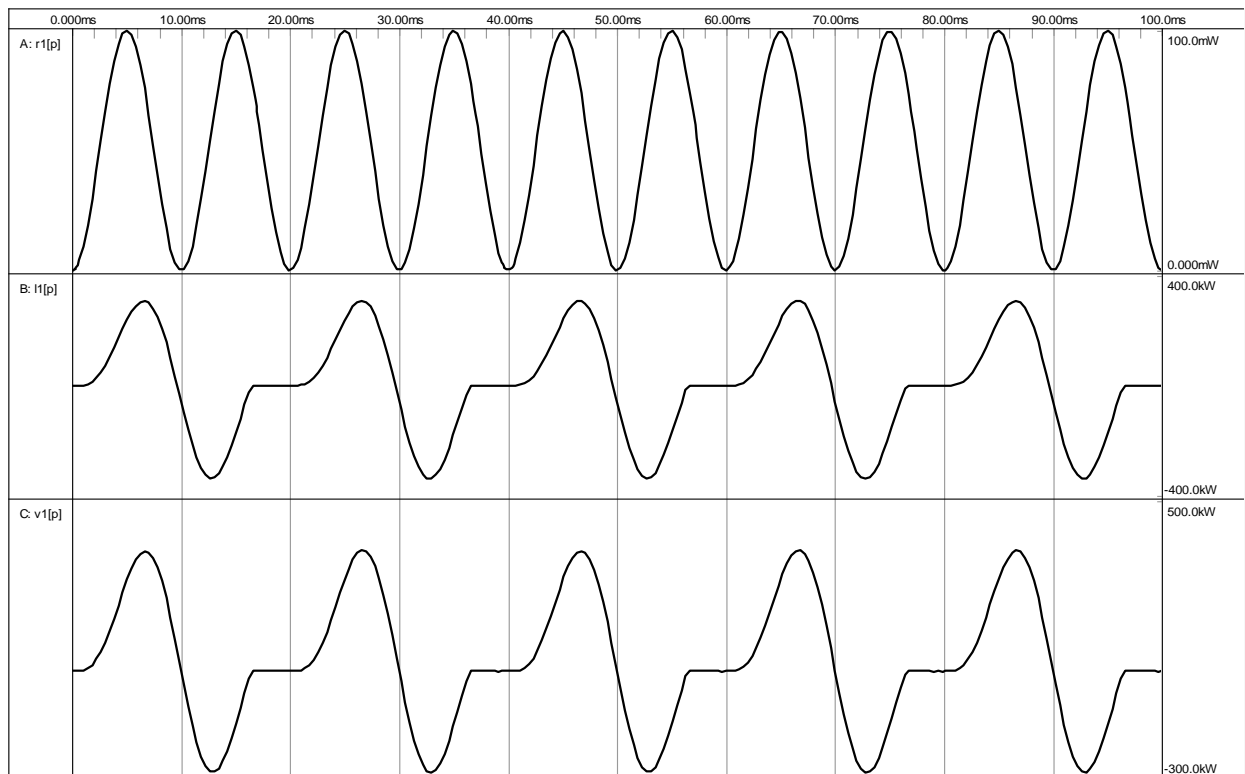Figure 12: Schematic diagram for the RL parallel circuit

Figure 13: Waveforms of the RL parallel circuit

Further analysis has been extended to RC combination in parallel and the results shows

pertinent values[20]. It should be noted here that connecting the RC circuit in parallel is again form the

tank circuit but the effect is not as strong as the RL circuits. Thereby, the analysis is performed without connecting any diode in between. In industrial stand, a fly-back diode will normally be connected in parallel with capacitor or inductor. With all the feasible points and features, the RC parallel circuit has been simulated (figure 14).
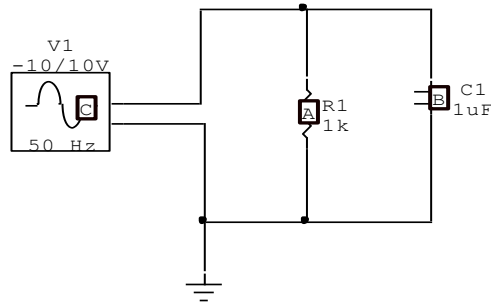

Figure 14: Schematic diagram for the RC parallel circuit

The value at point 'A' is 99.75 mille Watt max. and 508.67 micro Watt min. Likewise the value at point 'B' is +15.68 mille Watt as max. and -15.60 mille Watt as min. The total supplied power, which has 'C' designation, shows the max. as +102.3 mille Watt and the min as -2.003 mille Watt. Figure 15 reveals these results graphically for comparison-purpose.
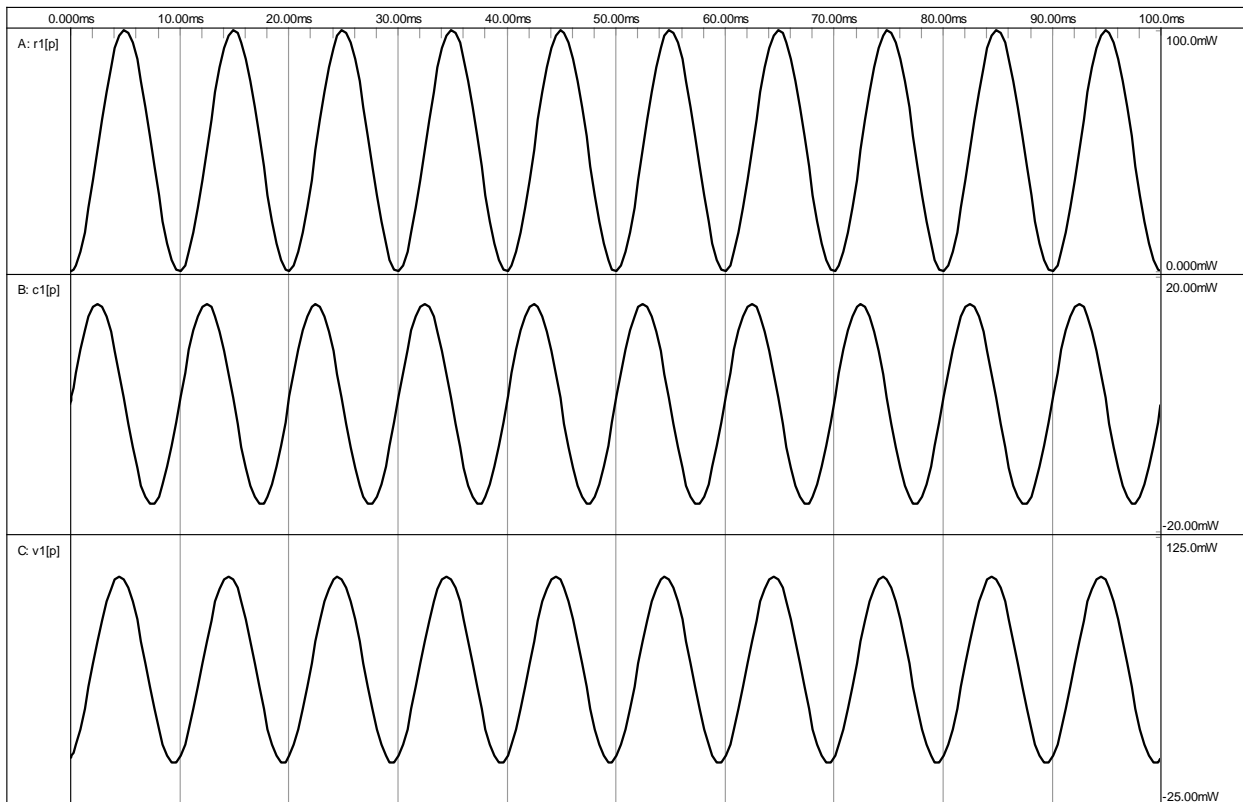

Figure 15: Waveforms of the RC parallel circuit

Conclusion

a) The power divider rule for the DC circuit that published in 2006, exactly works for the AC circuit.

b) The total supplied power is equal to the sum of individual components' power regardless of input sources.

c) In series configuration of components, the feasibility for the oscillation is extremely low.

d) In parallel configuration of components, the feasibility for the oscillation is very high and therefore an inter-connecting-component (diode) is suggested.

e) Resistive components' power is very stable no matter what the adjacent component is.

f) The reactive inductance and reactive capacitance does not affect very on resistive components.

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