

Effect of Different Component Values on 3-Stage Type-B Pulse Forming Network

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Abstract: The line-type pulse generators are generally not produce as rectangular as the pulse generated by the hard-tube pulser. Moreover, the line-type pulse generator usually has a longer rise and fall time and has oscillation on the top of the pulse. Overshoot on the leading and trailing edges is familiar kind of distortion. These distortions of the pulse shape may be reduced by special network design. This work proposes the design of a 3-stage type-B pulse forming network and the performance of the design have been studied to evaluate the effect of output parameters for different load resistance values. The results are evaluated for different load resistance value while keeping the other components value as static. The characteristic impedance for the design was selected as 50Ω. In this paper, input applied voltage of 1KV is considered for the design and result evaluation purposes. The results are evaluated to see the effect of load currents (I_L), capacitor currents (I_C), inductor currents (I_L) and capacitor voltages (C_V) for different load resistances.

Keywords: Pulse forming network, type B network, 3-stage ladder network, load current.

1. Introduction

The transmission line is generally composed of passive components with distributed resistances, inductances and capacitances that can transmit signals and produce perfectly rectangular pulses into a matched load. These transmission lines have certain limitations. The major limitation is the excessive length of cable required to generate a pulse of even a few microseconds duration. This excessive size of length may be overcome by using a lumped parameter transmission line. A lumped parameter line consists of discrete inductors and capacitors such that the characteristics of a transmission line are approached. The design of a lumped parameter line permits considerable flexibility in the choice of the pulse duration time and the characteristic impedance. A major disadvantage of the lumped parameter line used for pulse generation is its pulse shape. Rise and fall times are limited by parameter choice. It was impossible to generate an ideal rectangular pulse by means of a lumped-parameter network; the theoretical pulse that is chosen should intentionally have finite rise and fall times. The overshoots and oscillations in the pulse can be reduced to any desired degree by using a sufficient number of sections.

Guillemin developed the required pulse-generating network by placing the resonant L-C sections in parallel. A closer approximation is developed by using more sections. Networks of the form shown in Fig. 1 are inconvenient for practical use since the inductors have appreciable distributed capacitance and the capacitors have different values.

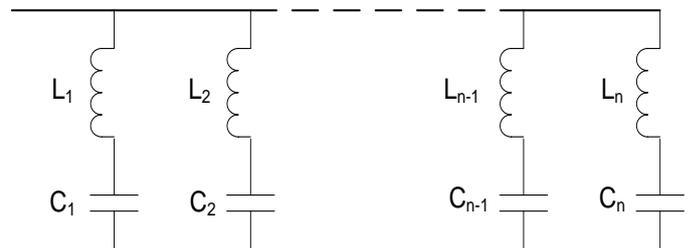


Figure 1: Type C- Network

Consequently, it is advantageous to devise equivalent networks which avoid these problems. There are many possible equivalent networks since, from the mathematical view point, all networks having the same impedance function are equivalent. There are many mathematical operations which yield such equivalent networks. The three most useful and practical networks are derived from expansion of the impedance function by Foster's Theorem and expansion of both the impedance and admittance function by Cauer's extension of Foster's Theorem. These networks are shown in Fig. 11-10.

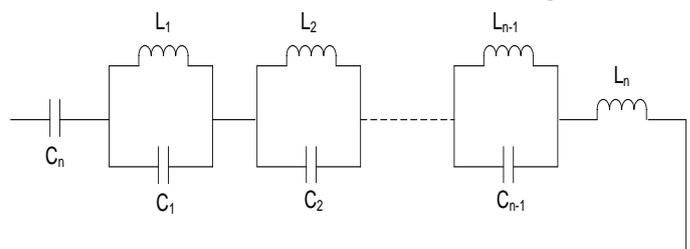


Figure 2: Type A- Network

Other equivalent networks may be developed by utilizing

combinations of the mathematical techniques used to derive the networks in Fig. 11-10. The design of a linear pulse forming network (PFN) for constant load impedance is relatively easy to design than the networks with nonlinear or time-varying load. The model for nonlinear loads can also be designed but this kind of load affects the performance of the PFN network in practical applications.

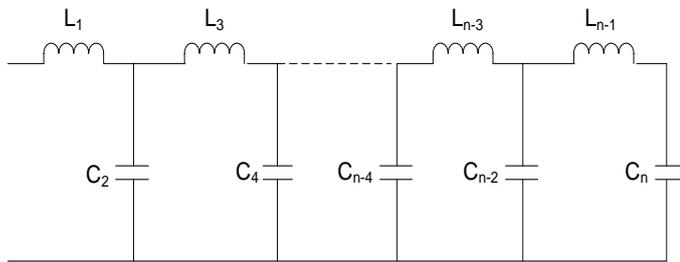


Figure 3: Type B- Network

In this paper, type B ladder network has been studied and analyzed to evaluate the effect of different values of passive components used. For this kind of network, the results are evaluated for consequent 3 sections. Identical values of capacitances have been taken for the whole network. The network capacitance and network inductance are determined

from the relations $L_n = Z_0 \tau$ and $C_n = \frac{\tau}{Z_0}$.

2. Methodology

The network is initiated by applying low ac voltage of 100 Volts. The input is then filtered and amplified. Input parameters have been loaded and are then applied to 3-stage type B PFN network. The remaining dc component, if any, is again filtered out and the output is generated for different load resistances, i.e. for 1Ω, 10Ω, 100Ω and 1KΩ. For this type of network, equicells are used. The value of resistances R were selected as 0KΩ while for inductors L and capacitors C , the selected values are 1μH and 0.1μF respectively. Different load resistances R_L were used to evaluate the parametric changes at output. The input voltage of 100 V ac is applied to the network with time interval T_{int} of 50 μs. The procedural steps followed for the performance evaluation of type B network is shown in the form of flow chart as fig. 4.

The optimization routines are different depending on the type of network, although the input parameters are the same. In an equicell network all cells are identical. One C_i value and one L_i value need to be specified and these will then be repeated N times to build a network. In a unicell network each cell can have a unique capacitor and inductor.

3. RESULTS & DISCUSSIONS

The results were taken to evaluate the effect of different values of load current I_L , capacitor current I_C , inductor current I_L and capacitor voltage C_V . The program was modified in FEM based software MATLAB to evaluate and optimize the results. Fig. 5 shows the output values for 1Ω load resistance.

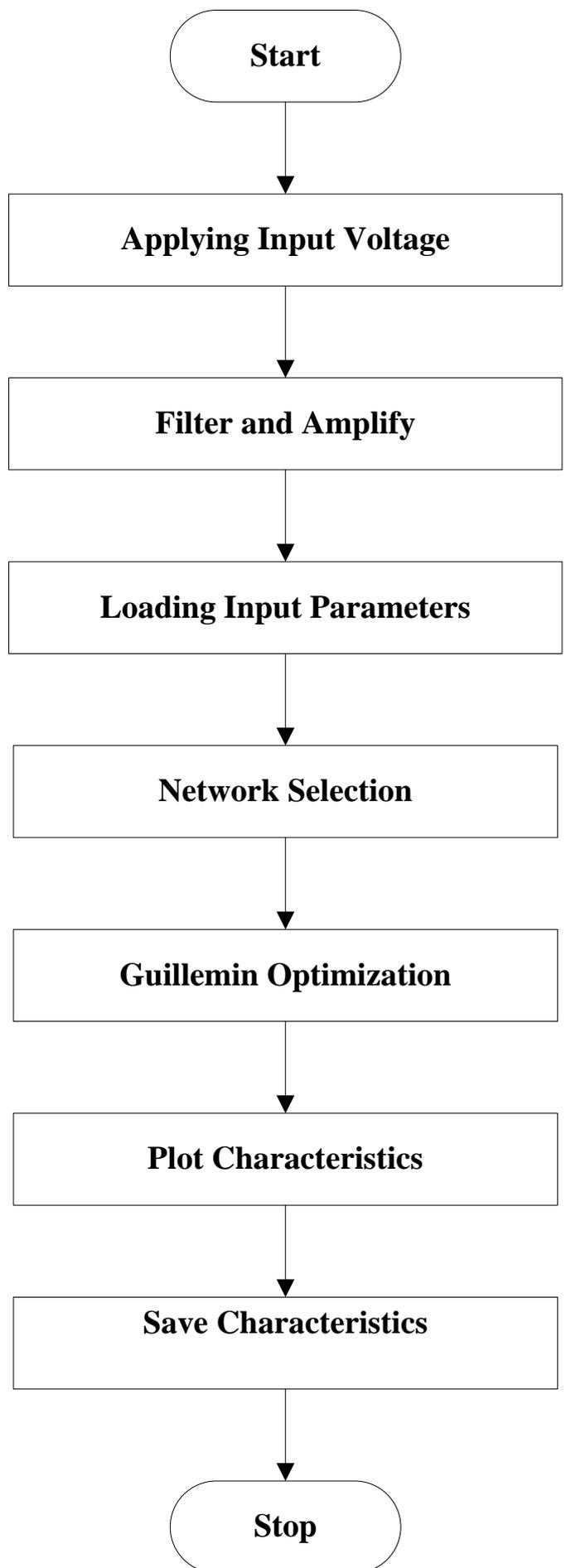


Figure 4: Flow chart showing procedural steps

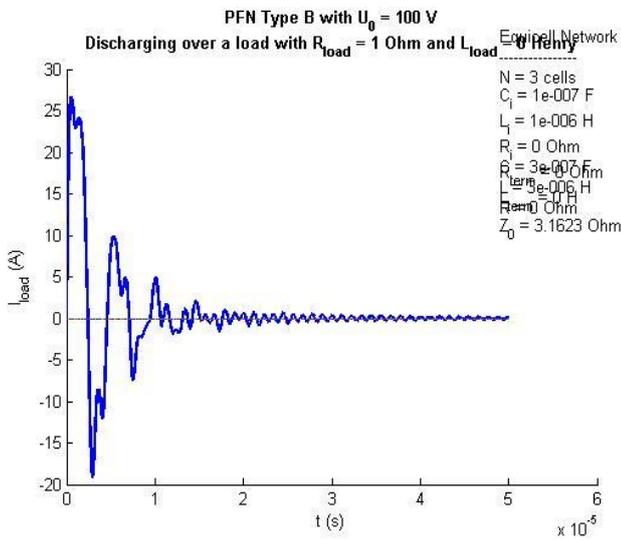


Fig. 5(a) Load current for $R_L=1\Omega$

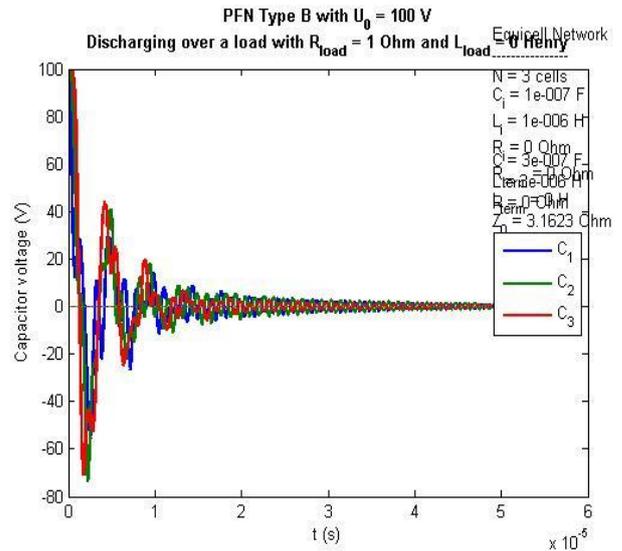


Fig. 5(d) Capacitor voltage for $R_L=1\Omega$

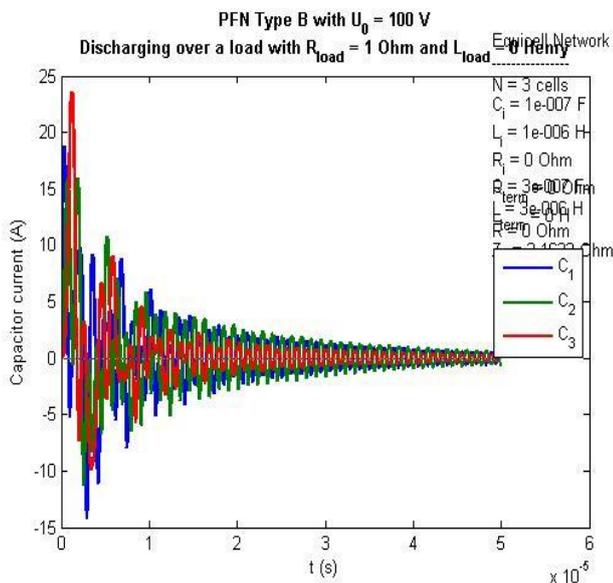


Fig. 5(b) Capacitor current for $R_L=1\Omega$

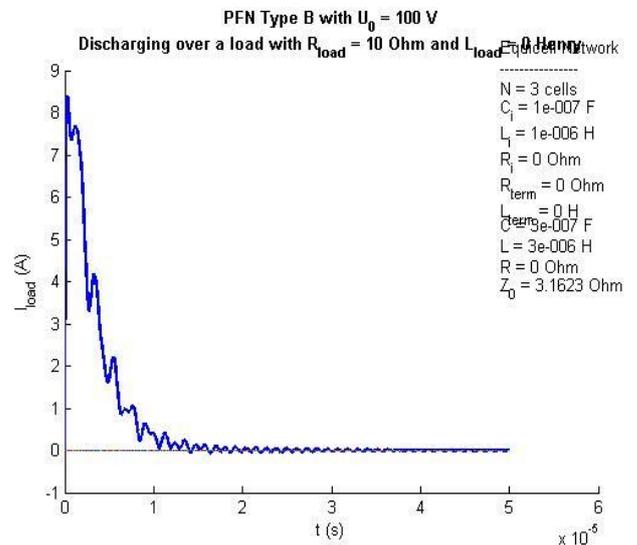


Fig. 6(a) Load current for $R_L=10\Omega$

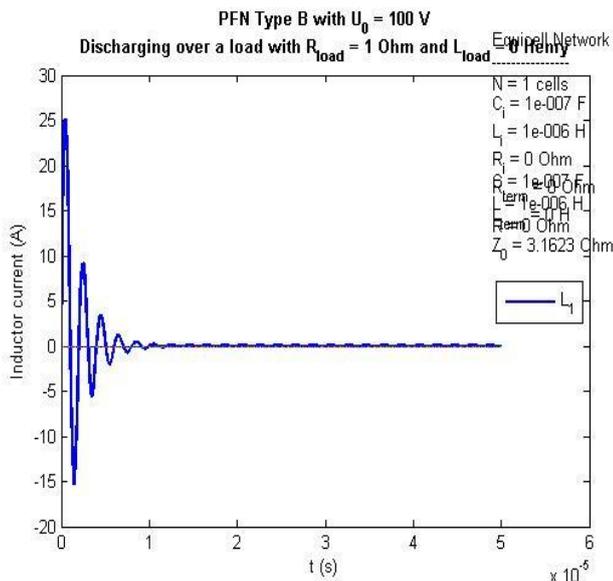


Fig. 5(c) Inductor current for $R_L=1\Omega$

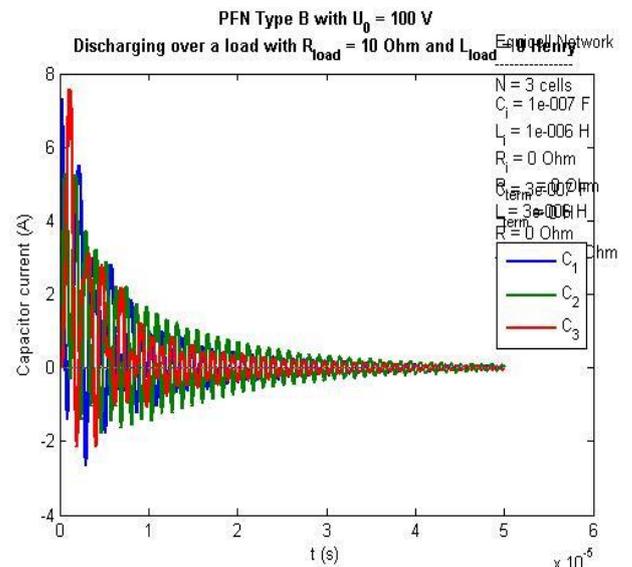


Fig. 6(b) Capacitor current for $R_L=10\Omega$

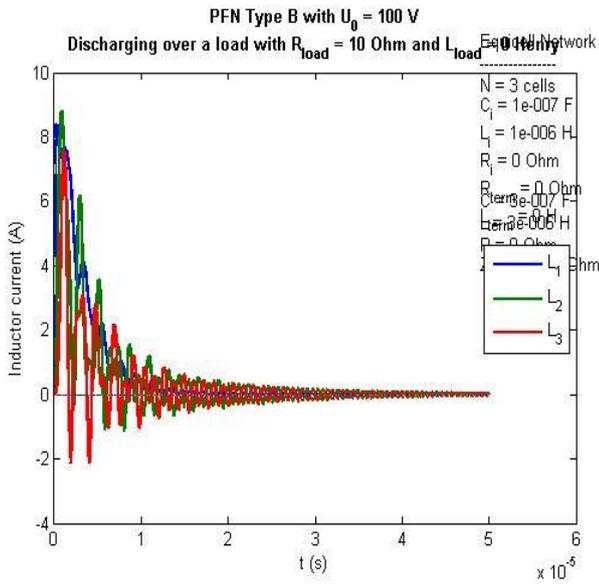


Fig. 6(c) Inductor current for $R_L=10\Omega$

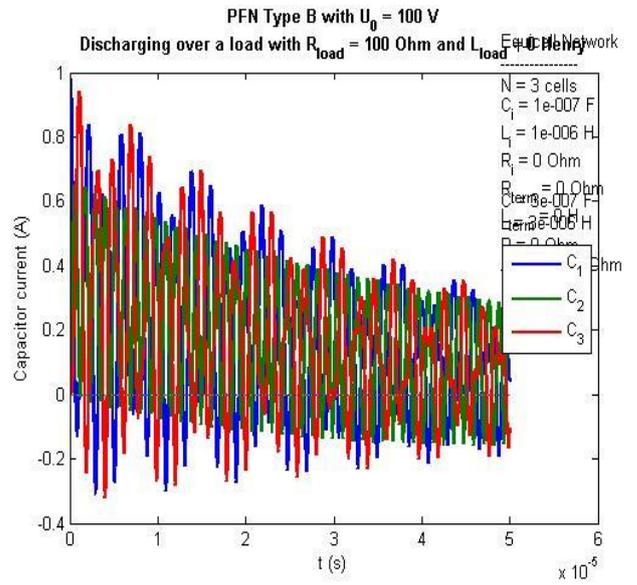


Fig. 7(b) Capacitor current for $R_L=100\Omega$

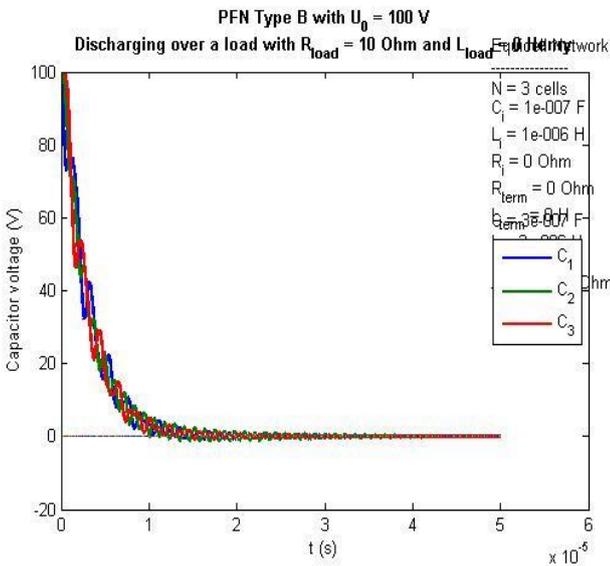


Fig. 6(d) Capacitor voltage for $R_L=10\Omega$

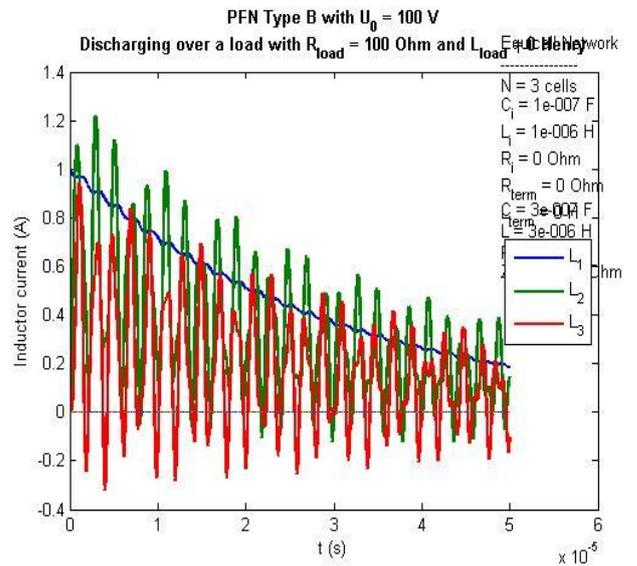


Fig. 7(c) Inductor current for $R_L=100\Omega$

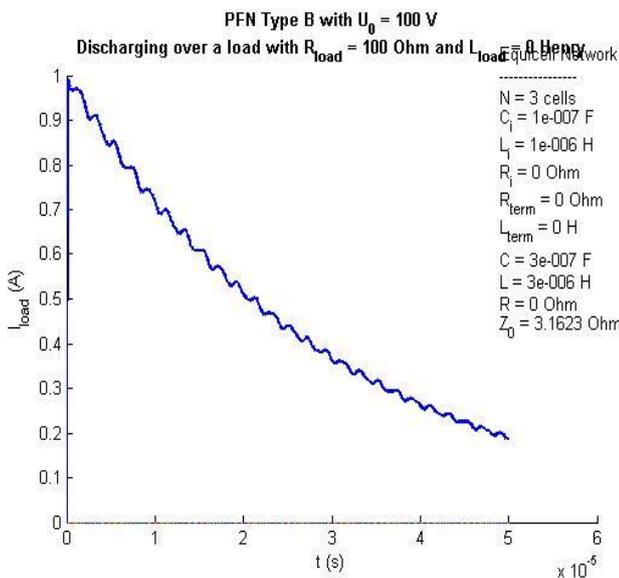


Fig. 7(a) Load current for $R_L=100\Omega$

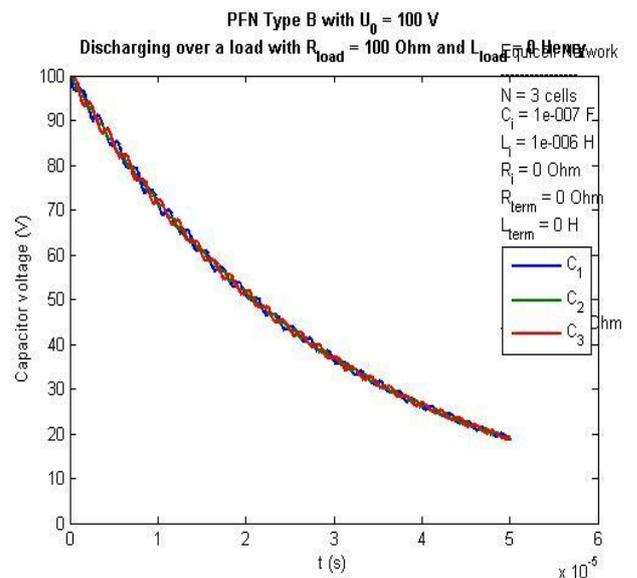


Fig. 7(d) Capacitor voltage for $R_L=100\Omega$

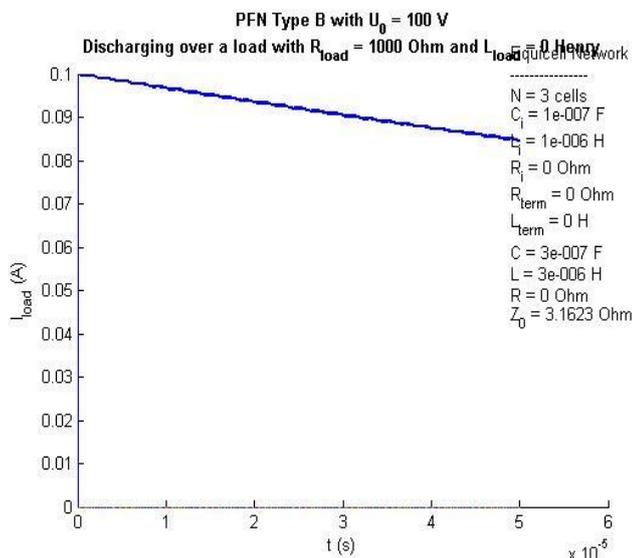


Fig. 8(a) Load current for $R_L=1K\Omega$

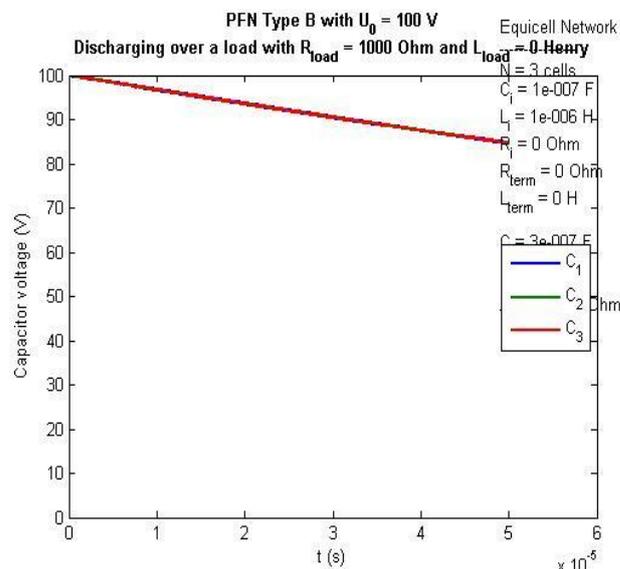


Fig. 8(d) Capacitor voltage for $R_L=1K\Omega$

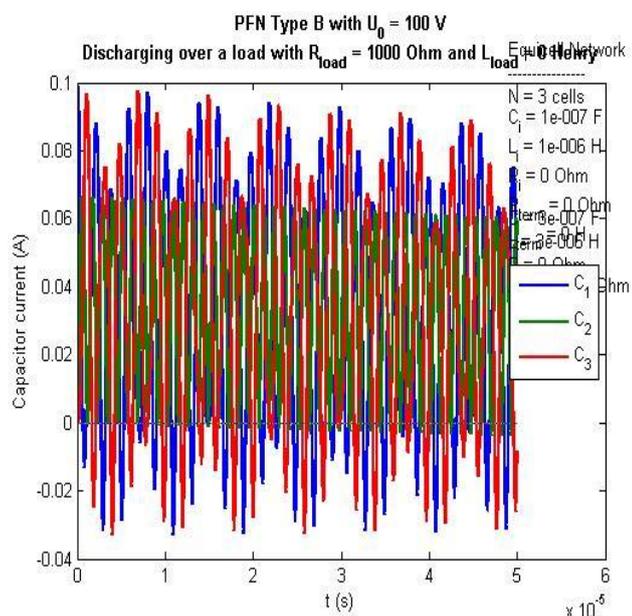


Fig. 8(b) Capacitor current for $R_L=1K\Omega$

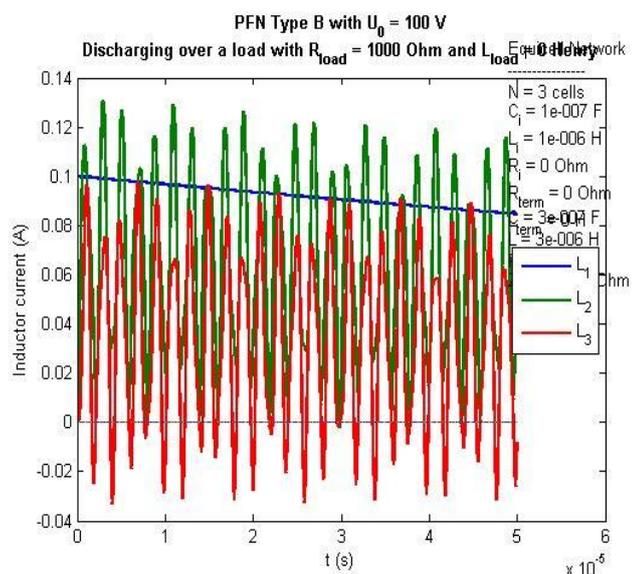


Fig. 8(c) Inductor current for $R_L=1K\Omega$

Similarly the results were noted while taken the value of load resistance as 10Ω and is shown in fig. 6. We kept on increasing the load resistance to see its effect on the component parameters. In this regard, the graphs have been noted on the value of load resistance 100Ω as shown in fig. 7. Similarly, the results were noted while taken the value of load resistance as $1K\Omega$ and is shown in fig. 8.

From the plots, it is clear that the frequency response of the network is limited due to inductance in the connections and the energy storage capacitors. The inductor is required in order to limit the maximum current capability. The current in the load decreases more rapidly so that the electrical energy stored is strongly reduced and the efficiency of the PFN is enhanced. A pulse shaping network comprises a distributed inductance and capacitance as energy storage device such as a coaxial line, multiple coaxial line, parallel plate transmission line, or two or more parallel-connected capacitors having an associated natural or added inductance. The accuracy depends on values of the equivalent circuits with respect to the various components (i.e. series inductance, and shunt capacitances, etc). Knowing these values, it is a simple circuit calculation to determine the approximate frequency response or the load current of such a circuit built by these passive components, to get the desired waveform in a specific network.

From the figures, it is clear that the lesser is the value of load, higher is the rise and fall time for the circuit. The slow rise and fall time for across the circuit for higher load value is due to the increased leakage inductance of the circuit. The fundamental component of the waveform can be estimated by the primary capacitance and the series inductance of the circuit. The leakage and loop inductance make up a series inductance which is almost twice the designed value and cannot be changed [18]. The primary capacitance could be lowered to shorten the rise and fall time, but in doing so the peak voltage would drop to an unacceptable level. The distortion increases with the increase in load resistance and is shown by the graphs between inductor current with respect to the time. As far as capacitor currents are concerned, it shows more distortion as the value of load current increases while for capacitor voltages, they shows same trend as that of load current.

4. CONCLUSION

The design is studied and the performance is evaluated for a 3-stage Type-B PFN network to produce the pulse shapes with sharp edges. The experiment is done by using different values of the load resistance. Four different load resistances have been taken. i.e. 1Ω , 10Ω , 100Ω and $1K\Omega$ and the interpretation for the plots described in the figures show a parabolic rise and fall of currents and voltages and ultimately become almost zero. Moreover, the simulation results show no significant differences in the rise and fall time for different cases, with and without consideration of losses. However the losses increase with the increase in the value of load.

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